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SNAKE RIVER BIRDS OF PREY NATIONAL CONSERVATION AREA

1994 ANNUAL REPORT

U.S. DEPARTMENT OF THE INTERIOR

Bureau of Land Management
Boise District, Idaho

National Biological Survey
Raptor Research and Technical Assistance Center

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.

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SNAKE RIVER BIRDS OF PREY NATIONAL CONSERVATION AREA RESEARCH AND MONITORING ANNUAL REPORT 1994

Karen Steenhof
Editor

NOT FOR PUBLICATION

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PREFACE

This report summarizes research and monitoring activities in the Snake River Birds of Prey National Conservation Area (NCA)during calendar year 1994. As in previous years, the main research effort in the NCA was the BLM/IDARNG Research Project.

National Conservation Area

The Snake River Birds of Prey National Conservation Area was established by Congress in August 1993. This Act provides permanent protection and establishes a management mandate for the area. During 1994 an interim draft management plan was developed for the NCA by Bruneau Resource Area, BLM and Raptor Research and Technical Assistance Center (RRTAC) personnel.

In 1994, RRTAC's main effort was conducting the cooperative BLM/IDARNG Project and coordinating other research and monitoring in the NCA. RRTAC also conducted numerous technical assistance actions, primarily requests from the RRTAC literature systems.

BLM/IDARNG Research Project

Field Studies: This was the fourth and final year of intensive field work for the 5 component studies of this 6-year research project (Table 1). Studies continued at full intensity with more than 75 people in the field. Results of these efforts are presented in the first half of the progress reports of this volume.

Project Integration: Principal accomplishments were similar to 1993 Integration efforts. In addition to a Project Integration Workshop in November, an Integration Team Meeting and Monitoring Workshop took place in March 1994. The latter consisted of project members and management personnel from BLM and IDARNG. A report of the integration effort is presented in the first half of this volume.

Other Research and Monitoring in the SRBOPNCA

Considerable work, other than the BLM/IDARNG Project, including long-term monitoring, continued in the NCA by RRTAC, BLM staff, and cooperators. Cooperators consisted of personnel from other agencies, universities, and private industry, as well as private individuals. These investigations are reported in the second half of the progress reports of this volume.

Technology Transfer

Although the main thrust for 1994 was conducting the BLM/IDARNG Research Project and continuation of cooperative research projects, work still continued on Technology Transfer. Eleven scientific papers were published and/or accepted for publication, and 2 BLM reports were published in 1994. RRTAC staff and associates made 41 technical presentations at various meetings and workshops.

Table 1. Component Studies of the BLM/IDARNG Research Project

Study 1.	Raptor Distribution and Use of the Orchard Training Area (OTA) and Adjacent Areas. Christine Watson and Eric Atkinson, Principal Investigators. Raptor Research Center, Boise State University.
Study 2.	Raptor Habitat Use and Foraging Behavior. John Marzluff, Principal Investigator, Greenfalk Consultants.
Study 3.	Raptor Nesting Densities and Reproductive Success. Michael N. Kochert, Robert N. Lehman, and Karen Steenhof, Principal Investigators. Raptor Research and Technical Assistance Center, NBS.
Study 4.	Townsend's Ground Squirrel Abundance, Procuctivity, and Habitat Relationships. Beatrice Van Horne, Principal Investigator. Colorado State University.
Study 5.	Vegetation Classification/Description and the Ability of Soils/Vegetation to Support Ground Squirrel and Jackrabbit Populations. Stephen Watts, Principal Investigators. Raptor Research and Technical Assistance Center, NBS.
Study Integration	John Rotenberry, Integration Leader. University of California, Riverside.
Technical Advisory and Review Panel	Michael Collopy, NBS Forest and Range Science Center, Corvallis, Oregon; Brian Maurer, Brigham Young University, Provo, Utah; Graham Smith, U.S. Fish and Wildlife Service Office of Migratory Bird Management Patuxent, Maryland; and Jay Anderson, Idaho State University, Pocatello, Idaho

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COOPERATING AGENCIES AND INSITITUTIONS

Albertson's College of Idaho
Boise State University, Raptor Research Center
Colorado State University
Conservation Research Foundation
Greenfalk Consultants
Idaho Army National Guard
Idaho Department of Fish and Game
Idaho Department of Transportation
Idaho Department of Water Resources
Idaho Power Company
Idaho State University
PacifiCorp
Peregrine Fund; World Center for Birds of Prey
University of Idaho
University of New Mexico
U.S. Army Chemical Engineering and Research Center
U.S. Army Corps of Engineers, CERL
U.S. Fish and Wildlife Service, Idaho State Office
U.S. Forest Service Intermountain Research Station
U.S. National Biological Survey
  Bird Banding Laboratory
  Patuxent Science Center
  Alaska Science Center
Utah State University
Weber State University

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PART I

TECHNOLOGY TRANSFER

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8 Feb 94	**Knick, S.T.**, and J.T. Rotenberry. Use of satellite imagery to determine landscape characteristics important for breeding passerine birds in southwestern Idaho. Annual Meeting, Oregon Chapter, The Wildlife Society, Bend, Oregon
19 Feb 94	**Lehman, R.N.** Status and management of raptors in the Snake River Birds of Prey National Conservation Area. 15th Annual Klamath Basin Bald Eagle Conference, Klamath Falls, Oregon.
19 Feb 94	**Lehman, R.N.** Status of bald eagles in Idaho. 15th Annual Klamath Basin Bald Eagle Conference, Klamath Falls, Oregon.
5 April 94	**Fuller, M.R.**, W.S. Seegar, and P. Howey. The use of satellite systems for the study of bird migration. 40th Anniversary Scienfitic Conference on Bird Migration. Society for the Protection of Nature in Israel, Eilat, Israel.
8 April 94	**Wilber, P.G.** Patterns of parasite infection in Townsend's ground squirrels (*Spermophilus townsendii*) during and following a drought. University of New Mexico Biology Department Research Day, Albuquerque, New Mexico.
22 April 94	**Wilber, P.G.** Patterns of helminth infection in Townsend's ground squirrels (*Spermophilus townsendii*) following a drought. Annual Meeting, Southwestern Association of Parasitologists, Emporia, Kansas.
13 June 94	**Lehman, R.N.** Raptor ecology. Seminar, Sawtooth Science Institute of Sun Valley, Boise, Idaho.
23 June 94	**Marti, C.D.**, and M.N. Kochert. Red-tailed hawk and great horned owl: are they diurnal/nocturnal equivalents? North American Ornithological Conference, Missoula, Montana.
23 June 94	**Prokop, R.S.**, and J.M. Marzluff. Wintering ecology of prairie falcons in the Snake River Birds of Prey Area. North American Ornithological Conference, Missoula, Montana.
23 June 94	**Rotenberry, J.**, and S. Knick. Habitat fragmentation and shrubsteppe birds. North American Ornithological Conference, Missoula, Montana.
24 June 94	**Marzluff, J.M.** The influence of resource distribution and signaling medium on foraging by common ravens. North American Ornithological Conference, Missoula, Montana.

24 June 94	**McFadzen, M. E.**, and J.M. Marzluff. The post-fledging period: a critical time in the life of a prairie falcon. North American Ornithological Conference, Missoula, Montana.
24 June 94	**Schueck. L.S.**, J.M. Marzluff, M. Vekasy, M.R. Fuller, and W.S. Seegar. Migration routes and winter ranges of golden eagles. North American Ornithological Conference, Missoula, Montana.
25 June 94	**Knick, S.**, and J. Rotenberry. Landscape and local habitat attributes associated with temporal variation in persistence of shrubsteppe birds. North American Ornithological Conference, Missoula, Montana.
26 July 94	**Kochert M.N.** Research and monitoring in the Snake River Birds of Prey National Conservation Area. Presentation to the Golden Eagle Chapter of the Audubon Society, Boise, Idaho.
9 Aug 94	**Munger, J.C.**, M.A. Caughlin, and S. Knick. Density and thermal regime of harvester ant colonies: effects of sagebrush. 79th Annual Meeting, Ecological Society of America, Knoxville, Tennessee.
11 Aug 94	**Wilber, P.G.** Patterns of parasite infection in Townsend's ground squirrels (*Spermophilus townsendii*) during and following a drought. Annual Meeting, American Society of Parasitologists, Ft. Collins, Colorado.
21 Aug 94	Schueck. L.S., J.M. Marzluff, M. Vekasy, **M.R. Fuller**, and W.S. Seegar. Migration routes and winter ranges of golden eagles. International Ornithological Congress, Vienna, Austria.
22 Aug 94	**Knick, S.** New concepts in landscape ecology for managing wildlife on rangelands. Sustaining Rangeland Ecosystems Symposium, La Grande, Oregon.
25 Aug 94	**Fuller, M.R.**, W.S. Seegar, and P. Howey. Radio tracking via satellites for avian conservation. 21st International Ornithological Congress, Vienna, Austria.
23 Sep 94	**Wilber, P.G.**, and D. W. Duszynski. The effect of parasites on Townsend's ground squirrels at the Snake River Birds of Prey Area, Idaho. First Annual Meeting, The Wildlife Society, Albuquerque, New Mexico.
23 Sep 94	**Olson, G.S.** and K.P. Burnham. Improving abundance estimates for open populations using the death only case of the Jolly-Seber model. First Annual Meeting, The Wildlife Society, Albuquerque, New Mexico.

23 Sep 94	**Van Horne, B.** A life table approach to identifying quality habitat in crunch year: an example from Townsend's ground squirrels in the Snake River Birds of Prey Area, Idaho. First Annual Meeting, The Wildlife Society, Albuquerque, New Mexico.
26 Sep 94	Dyer, D., S. Knick, M. Fuller, and T. Zarriello. Geographical information systems and remote sensing technology at the Raptor Research and Technical Assistance Center. First Federal Geographic Technology Conference, Exposition, and Data Mart. Washington, D.C.
20 Oct 94	**Kochert, M.N.** Ecological and management implications of 25 years of research in the Snake River Birds of Prey National Conservation Area. Graduate Seminar. Oregon State University, Corvallis, Oregon.
24 Oct 94	**Carpenter, L.B.** Survey methods for nesting prairie falcons in the Snake River Birds of Prey Area. Boise State University Seminar for Biology Course on Raptor Survey Techniques, Boise, Idaho.
24 Oct 94	**Lehman, R.N.** Assessing abundance and nesting success of benchland raptors in the Snake River Birds of Prey Area--an evaluation of methods. Boise State University Seminar for Biology Course on Raptor Survey Techniques, Boise, Idaho.
31 Oct 94	**Atkinson, E.C.** Application of semivariogram analysis to raptor point-count surveys. Boise State University Seminar for Biology Course on Raptor Survey Techniques, Boise, Idaho.
31 Oct 94	**Watson, C.R.B.** Point-count survey designs, repeated measures, and their statistical analysis. Boise State University Seminar for Biology Course on Raptor Survey Techniques, Boise, Idaho
3 Nov 94	**Ellsworth, E.A.**, and J.R. Belthoff. Postfledging behavior of western screech-owls: the effect of dominance on timing of dispersal. Annual Meeting, Raptor Research Foundation, Flagstaff, Arizona.
3 Nov 94	**Heath, J.**, and A.M. Dufty. Activity and corticosterone levels in food restricted post-fledging American kestrels (*Falco sparverius*). Annual Meeting, Raptor Research Foundation, Flagstaff, Arizona.
3 Nov 94	**Lehman, R.N.**, L.B. Carpenter, K. Steenhof, and M.N. Kochert. Assessing abundance and nesting success of benchland raptors in the Snake River Birds of Prey National Conservation Area--an evaluation of methods. Annual Meeting, Raptor Research Foundation, Flagstaff, Arizona.

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3 Nov 94	Braun, C.E., J.H. Enderson, **M.R. Fuller**, Y.B. Lingart, and C.D. Marti. Northern goshawk and southwestern forest management: a review. Annual Meeting, Raptor Research Foundation, Flagstaff, Arizona.
4 Nov 94	**Marti, C.D.**, and M.N. Kochert. Red-tailed hawk and great horned owl: are they diurnal/nocturnal equivalents? Annual Meeting, Raptor Research Foundation, Flagstaff, Arizona.
4 Nov 94	Schueck. L.S., J.M. Marzluff, M. Vekasy, **M.R. Fuller**, and T.J. Zarriello. Migration routes and winter ranges of golden eagles. Annual Meeting, Raptor Research Foundation, Flagstaff, Arizona.
6 Nov 94	**Kimsey, B.A.** Ranges IV Workshop. Annual Meeting, Raptor Research Foundation, Flagstaff, Arizona.
15 Nov 94	**Marzluff, J.M.** Social behavior of ravens. Seminar, The Peregrine Fund, Boise, Idaho.
21 Nov 94	**Kochert, M.N.** Effectiveness and biases of aerial surveys for golden eagles and other raptors. Boise State University Seminar for Biology Course on Raptor Survey Techniques, Boise, Idaho.
21 Nov 94	**Steenhof, K.** The midwinter bald eagle survey. Boise State University Seminar for Biology Course on Raptor Survey Techniques, Boise, Idaho.

PART II

PROGRESS REPORTS

Raptor Abundance and Reproductive Success in the Snake River Birds of Prey National Conservation Area--1994

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ANNUAL SUMMARY

*In 1994, the number of prairie falcon (**Falco mexicanus**) pairs (160) in the Snake River Birds of Prey National Conservation Area (NCA) was lower than in any year that complete surveys were conducted. Numbers of pairs in 8 randomly selected 10-km stretches were also the lowest ever recorded and well below the long-term average. Occupancy of historical prairie falcon nesting areas was highest in canyon stretches west of the Orchard Training Area (OTA) "shadow," and lowest east of the "shadow." Nesting success inside the OTA shadow was not significantly lower than success west and east of the shadow. Both the number of young prairie falcons produced per nesting attempt in the NCA (3.06) and the number of young per pair (2.71) were higher than the long-term average. Golden eagle (**Aquila chrysaetos**) occupancy in the NCA was similar to 1991-1993 levels. Reproduction declined sharply from 1993 levels. Number of young eagles fledged per pair (0.54) was lower than the previous 6 years. Golden eagle reproduction (young per pair) in the NCA was lower than in the Comparison Area. Thirty-four percent of historically occupied ferruginous hawk (**Buteo regalis**) nesting areas were occupied. Two new ferruginous hawk nesting areas were found. We found 151 occupied raptor nesting areas on the benchlands, 45 more than in 1993. These included 18 ferruginous hawk, 11 northern harrier (**Circus cyaneus**), 87 burrowing owl (**Speotyto cunicularia**), and 35 short-eared owl (**Asio flammeus**) pairs. Relative abundance of benchland nesters was higher inside than outside the OTA, and the difference approached significance. Nesting success of ferruginous hawks, northern harriers, and short-eared owls inside and outside the OTA could not be evaluated because of low sample sizes. Nesting success for burrowing owls did not differ significantly inside and outside the OTA. Habitat analyses indicated that hills, artificial perch and nest structures, agriculture, soil depth, percent shrub cover, shrub density, minimum canopy height, mean shrub height, and livestock grazing may be related to nest site selection on the bench. Burrowing owl nesting areas in the OTA were closer*

to roads and firing ranges than random points were. Distances of roads, bivouac sites, artillery firing points, and firing ranges to successful and unsuccessful burrowing owl nests did not differ significantly. Short-eared owl nests were closer to firing ranges in the OTA than were random points, but were not significantly closer to roads.

OBJECTIVES

1. Assess 1994 prairie falcon abundance and long-term population trends in the Snake River Birds of Prey National Conservation Area (NCA) and compare 1994 falcon nesting densities inside and outside the Orchard Training Area (OTA) Shadow.

2. Assess prairie falcon reproduction at preselected nesting areas and compare estimates of productivity to long-term trends in the NCA.

3. Compare prairie falcon nesting success and productivity inside and outside the OTA Shadow.

4. Compare 1994 golden eagle abundance and productivity in the NCA and Comparison Area.

5. Assess the relative abundance and reproductive success of benchland-nesting raptors inside and outside the OTA.

6. Compare habitat and land use characteristics of occupied benchland nesting areas to randomly selected unoccupied areas on the bench.

7. Assess ferruginous hawk occupancy and nesting success at historical nesting areas in the NCA.

Study 3's main objective is to determine if nesting densities and reproduction of the major raptor species in the NCA have changed over time and if any such changes can be correlated with military use and fire occurrence. In addition, a long-term approach for monitoring raptor nesting populations will be recommended based on this research.

The 1994 field season was the fifth and last year of the study. Field work emphasized Tasks 1, 2, 3, and 4 of the Study 3 Plan (Kochert et al. 1991). For Task 1 (the bench survey), we conducted a quadrat survey similar to that used in 1993, visited most historical bench nesting areas, and attempted to assess fate at all occupied nesting areas found in 1994. General approaches for Tasks 2 and 3 (comparison of past and present raptor nesting densities and OTA effects) changed slightly in 1994. We did not compare prairie falcon fledging weights inside and outside the OTA shadow for this report, but will do so for the Study 3 final report in 1995. We collected density and reproductive data on golden eagles and ferruginous hawks for Task 4 (burn effects), but we did not analyze burn effects in 1994. A preliminary analysis of burn effects was completed in 1993 (Lehman et al. 1993), and we plan further analyses for the final Study 3 report. We did not assess band recoveries or nest site fidelity (Task 5) in 1994. During habitat assessments on the bench, we used the same habitat variables used in 1992 and 1993 but collected data on 2 additional variables: shrub density and minimum canopy height.

METHODS

Prairie Falcon Abundance and Reproduction

Abundance.--In 1994, we surveyed all stretches of the Snake River Canyon and major side canyons within the NCA (Hammett to Walters Ferry) for prairie falcon nesting activity 3 times: once between 10 and 30 March; once between 2 and 20 May; and once between 31 May and 26 June. As in past years, some buttes and portions of side canyons (Walters Butte, Rock Cabin Spring, Little Hole, and Rattlesnake Spring nesting areas) were excluded from the survey area. Also, 1 area traditionally surveyed 3 times in previous years (Bruneau Flats) was surveyed only twice in 1994.

Each month, observers surveyed stretches of the canyon from standardized observation points, spaced at approximately 1-km intervals. Some side

draws consisting of small or broken cliffs were surveyed by walking. We also walked some cliff stretches when our presence at fixed observation points would have disturbed other target species of nesting raptors (e.g., golden eagles or ferruginous hawks). Most observation points were on the canyon floor so observers faced the potential nesting cliffs. Observations were made from the canyon rim along a few stretches where the view was obscured from below. Each observation point was surveyed for 2 hrs during each monthly survey. When the survey stretch was <1 km, survey time was proportionately less. Only 1 side of the canyon was surveyed from each observation point except where the canyon was very constricted. Before field work began, 12 blocks of observation points, each containing approximately the number of points that could be surveyed by a 2-person crew in 3 days, were identified. In March, the blocks were surveyed in a randomly selected order. The same order was used in the May and June surveys.

Observers recorded nesting activity of all raptors and ravens in field journals and on 1:24,000-scale U.S.G.S. topographic maps. To improve accuracy, we also plotted nests on black and white 1:24,000-scale aerial photographs. We also recorded observations of birds wearing colored leg bands, U.S. Fish and Wildlife Service leg bands, or other markers. A nesting area was considered occupied if territorial defense, courtship, or other reproductive activity was observed (U.S. Dep. Inter. 1992).

We analyzed results for the entire NCA and for 10-km stretches of the canyon delineated in U.S. Dep. Inter. (1979). We compared 1994 data with years when surveys of the entire area were complete (1976-1978, 1990-1993) and for certain 10-km stretches surveyed between 1976 and 1993. We analyzed nesting densities in each 10-km unit in relation to the amount of available cliff area, as calculated by Bentley and Hardyman (1978) and presented in U.S. Dep. Inter. (1979).

As in 1992 and 1993, the OTA "Shadow" (previously defined as 10-km Units 7, 8, and 9) was extended west to include 10-km unit 6, based on 1991 radio-telemetry results (Marzluff et al. 1991). We compared densities in the OTA Shadow (Units 6, 7, 8, and 9) with stretches southwest and southeast of the OTA.

Reproduction.--We assessed prairie falcon nesting success and productivity in the NCA for 2 treatment groups in 1994. Study 2 assessed reproduction at nesting areas where they radioed adults in 1994, and Study 3 assessed reproduction at a randomly selected sample of "control" nesting areas; i.e., those not radioed in 1994. Randomly selected control areas where we confirmed that ≥1 adult was wearing a radio from a previous year were excluded from analyses of radio effects.

Before the nesting season, all historical nesting areas in the canyon (10-km units 4-9 and 11-13) were stratified as east, west, or inside the OTA shadow, and nesting areas were randomly assigned to Study 2 or Study 3. The order of random selection determined which nesting areas would be studied and which would be back-up sites. As in 1991, 1992, and 1993 the target "control" sample size (based on power tests; Kochert et al. 1991) was 51 nesting areas. In 1994, target sample sizes for the 3 strata were the same as in 1992 and 1993 but differed slightly from the 1991 samples due to the OTA shadow configuration change described above. In 1994, target sample sizes were 12 nesting areas from 10-km units west of the OTA Shadow, 23 from units inside the OTA Shadow, and 16 from units east of the OTA Shadow. As in 1992 and 1993, we also selected 10 nesting areas east of the Integration Study Area (ISA) boundary (10-km units 14-17) to monitor reproductive success throughout the NCA. Nesting areas east of the ISA boundary were not used in the analysis of OTA effects.

We began monitoring selected "control" nesting areas in early March (prior to incubation), and continued observations up to the time of fledging. We checked all selected nesting areas during each of the 3 density surveys. If occupancy was not determined during the March survey, we selected replacement nesting areas from the list of backups in the original random order. We continued observations at the replaced nesting areas until we were certain they were unoccupied, usually after 6-8 hrs of observation.

Between early April and late May, we observed nesting areas from remote observation points to identify probable nesting scrapes. Each observation bout continued for up to 4 hrs. Criteria for

confirming scrape locations and thereby identifying probable breeding attempts included: observation of eggs in a scrape or nest; an adult observed in incubating posture; or observations of an adult falcon entering a scrape and remaining within the scrape for ≥1 hr. If scrape locations could not be identified during scheduled observation bouts, we climbed to locate scrapes. We continued observations at nesting areas where scrapes could not be identified to determine if nonbreeding pairs were present.

Nesting attempts were considered successful if ≥1 young reached 30 days of age (Steenhof 1987). Nestlings were aged at most nests by remote observations late in the brood-rearing period using an aging key (Moritsch 1983). We climbed to some nests to age young. Nest climbs to count fledging-aged young occurred when young were 30-35 days old. During nest climbs, young were weighed, examined for condition, and banded with a USFWS band on the right leg and a red anodized aluminum band with a unique alphanumeric code on the left leg. We also measured foot pad length, tarsal width, and length of the seventh primary. To control for observer bias, measurements were taken by only 4 people. Because of time and logistical constraints, we did not exchange personnel with Study 2 when broods were measured. Between 1990 and 1992, this was done to control for observer bias.

To compare productivity among years, we used only 1994 "control" nesting areas and excluded nesting areas from previous years where experimental disturbances, nest site enhancements, manipulations of eggs or young, trapping and tagging, or disease treatment occurred. This ensured that results were not biased by researcher manipulations. Analyses of percent of pairs successful were based on pairs selected for study prior to each nesting season. To assess the percent of nesting attempts successful, the analysis included only those breeding attempts confirmed during incubation and for which outcome was known. Number of young fledged per successful attempt was based on all control pairs for which complete fledge counts were obtained. Number fledged per pair and per attempt were estimated as the products of percent success and number fledged per successful attempt.

Golden Eagle Abundance and Reproduction

In 1994, we preselected all 39 historical golden eagle nesting areas in the NCA and 24 nesting areas in the Comparison Area (see Kochert et al. 1991) for observation. We surveyed all 63 nesting areas by helicopter or from the ground in conjunction with other raptor surveys. Helicopter surveys were conducted from a Bell 206 Jet Ranger on 14 March and 31 May. The purpose of the first survey was to determine if nesting areas were occupied and if eggs had been laid. We re-checked nesting areas with breeding pairs during the second flight to assess productivity. The March helicopter survey was conducted along the Snake River from Givens Hot Springs east to King Hill (A-334), and along the Pacific Power and Light (PP&L) transmission line from Miles 45 to 127. The May helicopter survey covered the canyon from Walters Butte to Glenns Ferry and the PP&L transmission line from Miles 45 to 120. In addition, some golden eagle nesting areas on the PP&L transmission line and selected areas in the canyon and Comparison Areas were surveyed from a helicopter on 28 April and 17 June, in conjunction with ferruginous hawk surveys. Helicopters were flown at speeds of 70-95 km/hr, and we hovered approximately 10 m from nests for 5-25 sec to view nest contents. No attempt was made to flush incubating birds or count eggs.

Nesting areas where occupancy or breeding status could not be ascertained during helicopter flights were surveyed from the ground. We conducted 1994 ground surveys in conjunction with prairie falcon density surveys in the NCA. Idaho Power Company personnel surveyed some nests in the Comparison Area from the ground. Six golden eagle pairs were used for Study 2's radio telemetry work (Marzluff et al., this volume).

Eagle pairs that showed no evidence of egg-laying after repeated observations were categorized as "nonbreeding." A "breeding attempt" was confirmed if an occupied nesting area contained an incubating adult, eggs, young, or any indication that eggs had been laid (e.g., fresh eggshell fragments in fresh nesting material). A breeding attempt was "successful" if ≥1 young reached 51 days of age (Steenhof 1987). A photographic aging key was used to age young (Hoechlin 1976). Eagle nests

checked after young had fledged were considered successful if: (1) a platform decorated this season was worn flat and contained fresh prey remains; (2) fresh fecal matter covered the back and extended over the edge of the nest; and (3) no dead young birds were found within a 50-m radius of the nest.

We calculated percent of pairs breeding in 1994 and earlier years from preselected pairs (Steenhof and Kochert 1982). Percent of nesting attempts that were successful was based on attempts confirmed during incubation. Nesting areas where researcher manipulations (experimental disturbances, nest-site enhancements, manipulations of eggs or young, trapping and tagging, or disease treatment) had occurred in 1994 or in previous years were excluded from analyses of percent success.

Ferruginous Hawk Occupancy and Reproduction

In 1994, we preselected 74 of 82 historically occupied ferruginous hawk nesting areas in the NCA for observation. These were classified as ISA or non-ISA areas. In the ISA, we classified nesting areas as benchland or canyon areas. We surveyed all 31 canyon nesting areas, 36 benchland areas, and 7 of 14 non-ISA areas. We also surveyed 1 non-preselected nesting area on the bench. Seven non-ISA areas were not surveyed due to time constraints and because they had been vacant for ≥10 years.

We observed canyon nesting areas during the March, May, and June prairie falcon density surveys. We surveyed benchland nesting areas in the ISA at least 3 times between 23 March and 3 July (see the Benchland section below). We surveyed non-ISA nesting areas at least twice. All occupied historical nesting areas were revisited until fate was determined. A nesting area was considered occupied if territorial defense, courtship, or other reproductive activity was observed (U.S. Dep. Inter. 1992).

In addition to ground surveys, helicopter surveys were conducted on 28 April and 17 June. These surveys included all nesting areas on the PP&L transmission line within the NCA and occupied nesting areas in the canyon and outside the ISA where breeding status was undetermined during ground surveys. We also checked some ferruginous hawk nesting areas by helicopter during the 31 May golden eagle survey.

We re-visited ferruginous hawk nesting areas found for the first time in 1994 as necessary to determine breeding status and nesting success. To report occupancy rates we used only preselected nesting areas. To report success rates we used all nesting areas confirmed during incubation (where eggs or an incubating adult were seen) and where fate was known. We considered nesting attempts successful if ≥1 young reached 31 days of age. Nestlings were aged using a photographic aging key (Moritsch 1985).

Nesting of Raptors on the Benchlands

Relative Abundance.--To assess the relative abundance of raptors nesting on the benchlands north of the canyon, we searched randomly selected quadrats inside and outside the OTA. The goal of quadrat surveys was to locate as many nesting areas within the sampling units as possible. As in 1993, quadrats were 6 km^2 and had a north-south orientation. North-south boundaries were 2 km long, and east-west boundaries were 3 km long. Target species for relative abundance assessments included the ferruginous hawk, northern harrier, burrowing owl, and short-eared owl.

To select quadrats, we superimposed a 6-km^2 cell grid on the ISA using the Geographic Information System (GIS). To avoid duplicating 1993 quadrat boundaries, we changed the starting point for the grid overlay in 1994. We rejected cells falling on the ISA or OTA boundaries, within 250 m of the canyon rim, or within the Artillery Impact Area. We then randomly selected 50 cells as survey quadrats from those remaining on the grid. Quadrat boundaries were drawn on U.S. Geological Survey 1:24,000-scale topographic maps and orthophoto quadrangles. For quadrats outside the OTA, we examined black and white 1:24,000-scale 1987 aerial photographs and used the GIS to assess amounts of agricultural development (irrigated or dry cropland and irrigated pasture) within each quadrat. We rejected those with ≥10% of their surface areas developed. We selected new quadrats as needed to assure a minimum sample size of 40

quadrats (15 inside the OTA and 25 outside). The extent of agricultural development in each selected quadrat was verified on the ground during the first field survey.

We sampled each quadrat twice during the nesting period. The target survey period during each survey was 6-12 hrs per quadrat. However, 1 quadrat with poor cover was surveyed for only 4.5 hrs and another with dense shrubs took 16.5 hrs to complete. To improve detection of owls, at least 1 survey began at dawn or ended at dusk. We conducted the first quadrat survey from 28 March to 29 April, and the second survey from 28 May to 7 July. Because nesting areas are more easily detected late in the breeding period when young are present (Steenhof 1987), we scheduled the second quadrat survey 4 weeks later than in 1993. One person usually surveyed each quadrat, and no observer surveyed the same area twice. We did not mark quadrat boundaries in the field; instead, we used maps and compasses and focused on geographic features to remain inside quadrats. We usually drove, and sometimes walked, all roads within each quadrat, pausing occasionally to scan for raptors. We then walked areas within quadrats not visible from roads. Observers usually walked line transects through quadrats, spaced at intervals determined by vegetation density and height. In areas with high, dense shrubs, transects were usually spaced 100-200 m apart. In open areas, transects were spaced 300-400 m apart. While walking, we tried to visually scan all areas not covered while driving. To ensure uniform coverage throughout each quadrat, we developed a strategy for searching before each quadrat survey. Observers judged when a quadrat had been adequately surveyed.

During quadrat surveys, we noted the location and behavior of all raptors observed. We considered a nesting area occupied if territorial defense, courtship, or other reproductive-related activity was observed (see U.S. Dep. Inter. 1992). Evidence for a breeding attempt included the presence of eggs or young or any field sign indicating that eggs were laid (e.g., adults in incubating posture, eggshell fragments in fresh nesting material--U.S. Dep. Inter. 1992). We tried to assess fate at all nesting areas where breeding attempts were confirmed using protocols described below for historical nesting areas.

When we suspected nesting activity within a quadrat, the observer immediately conducted a short search to locate the nest. If the nest could not be located within 0.5 hr, the survey resumed. We visited these areas later to locate nests. Follow-up visits at nesting areas found during the first survey were scheduled before the mean hatching date for each species. Visits to nesting areas found during the second quadrat survey were scheduled before the mean fledgling date for each species. Mean hatching and fledging dates were based on NCA nesting records.

When nests were found, observers plotted the locations on field maps using aerial photographs. To ensure that nests could be found during follow-up surveys, observers flagged a nearby shrub or a stake in shrubless areas no closer than 10 m from a nest, and recorded directions to the nest. When possible, the same observer who found a nest returned for follow-up surveys. Coordinates of nests, or the centroids of nesting areas where nests were not found, were established using the Global Positioning System (GPS) during habitat surveys (described below) in July and August.

To assess differences in relative abundance inside and outside the OTA, we classified quadrats based on whether or not occupied nesting areas (all species pooled) were found. We compared groups inside and outside the OTA using contingency table analysis.

Historical Nesting Areas.--In 1994, we preselected 204 of 237 raptor nesting areas on the ISA benchlands known to be occupied at least once in previous years. Time limitations prevented visits to all historical nesting areas, so we prioritized surveys by the year each was last occupied. We first checked all nesting areas occupied in 1992 and 1993. Nesting areas last occupied before 1992 were checked as time permitted. We considered a historical nesting area to be vacant if no signs of occupancy were detected during the egg laying and brood-rearing period for each species. Usually this required ≥ 3 checks during the nesting period. Initial visits at all nesting areas occurred between 23 March and 29 April, depending on nesting chronologies for each species.

As in 1993, we refined search protocols in 1994 to account for home range size differences among species. Search areas consisted of a circular plot centered on the historical nesting area or the centroid of a historical nesting area if >1 nest was used. Radii of search areas were 1 km for ferruginous hawk nesting areas, 400 m for short-eared owl and northern harrier nesting areas, and 300 m for burrowing owl nesting areas.

For ferruginous hawks, observers spent 1 to 1.5 hrs on site during each visit. We walked and scanned open ground and checked all rock outcrops and other raised substrates within a 1-km radius.

Nest searches at burrowing owl nesting areas had no time limit but were ≥0.5 hr. We visited each nesting area ≥3 times, often during early morning or late evening hours. During searches, we tried to examine all suitable badger (*Taxidea taxus*) burrows for signs of use (whitewash, prey remains, castings, etc.) within the prescribed radius (300 m).

In 1994, we tried to improve fate assessments and reduce the number of visits needed to assess fate at burrowing owl nests using a prototype underground camera system designed at the Lawrence Livermore National Laboratory, Livermore, California by Jim Woollett and John Christensen. The miniature optical lair explorer (MOLE) was a miniature camera mounted on a small tracked vehicle. We used it to view the contents of occupied burrows. The MOLE was 13 cm long, 9 cm wide, and 13 cm high. Lighting for the camera was provided by light emitting diodes (LED's) mounted around the tracked vehicle. The camera was mounted on top of and towards the front of the vehicle, and was able to rotate 360 degrees. The device was operated from a mobile console with a video monitor. The MOLE was attached to the monitor by an electric cable.

For short-eared owl and northern harriers, we searched the prescribed area (400-m radius) on foot. Both species flush from their nests only when observers are very close (Natl. Biol. Surv., unpubl. data); thus, during each visit we searched all shrub and dead Russian thistle (*Salsola iberica*) stands thoroughly. Many visits occurred as part of a short-eared owl radio-telemetry project conducted on the ISA benchlands in 1994 (see Rivest, this volume). As a result, most short-eared owl nesting areas were visited 5-10 times.

We revisited all occupied nesting areas just before fledging to determine success. Ferruginous hawk breeding attempts were considered successful if ≥1 young reached 31 days of age, and burrowing owl breeding attempts were considered successful if ≥1 young reached 28 days of age. We used photographic aging keys (Moritsch 1985, and J. Priest, Humane Society of Santa Clara, California, unpubl. data) to age nestlings of both species. Short-eared owl and northern harrier nesting attempts were considered successful if ≥1 young reached 20 and 24 days, respectively (Clark 1975, Steenhof 1987). We used descriptions of feather development to age nestlings of both species. For northern harriers, nestling ages were based on Bent (1961) and Watson (1977). For short-eared owls, nestling ages were based on Karalus and Eckert (1987) and Johnsgard (1988). Nest visits to confirm fate continued through 25 July. Visits to confirm short-eared owl post-fledging dispersal continued through 21 August.

Other Nesting Areas.--To locate nesting areas not recorded previously, we followed up all observations of reproductive-related activity involving any of the 4 target species reported by BLM/IDARNG project personnel. If nesting activity was observed by Study 3 personnel while traveling on the benchlands, observers conducted an immediate search of the area for evidence of a nesting attempt. We asked other study teams involved in BLM/IDARNG research to record observations on a standard data form. All nesting areas where breeding was confirmed were revisited later in the nesting season to determine nesting success. We scheduled visits according to the nesting chronologies of the 4 target species.

Assessment of Nesting Success.--To assess reproductive success of nesting raptors on the benchlands, we tried to determine fate at historically occupied nesting areas, nesting areas found during quadrat surveys, and nesting areas found opportunistically by Study 3 personnel and other study teams. We analyzed only those ferruginous hawk, northern harrier, and short-eared owl nesting attempts found during incubation (where adults in incubating position or eggs were observed).

We determined if burrowing owl pairs were found during incubation by backdating from age estimates of young obtained after young had emerged from

their burrows. If no young were observed at an occupied nesting area, we included the pair in success estimates if we found it before the median hatch date (20 May).

Habitat Assessments.--Habitat assessments in the ISA had 3 objectives: (1) to identify habitat characteristics associated with nest site selection; (2) to identify habitat characteristics associated with nesting success; and (3) to assess the relative availability of important habitat features inside and outside the OTA.

We used contingency table analyses (G-tests) to assess differences in categorical habitat variables between nests and random points, and between successful and unsuccessful nesting areas. We used t-tests to assess similar differences in continuous habitat variables. Habitat characteristics at random points inside and outside the OTA were compared using G-tests and t-tests. We used the SAS statistical package (SAS Statistical Institute 1990) for all statistical analyses.

Study 3 field crews collected habitat data during a final visit after fledging. These visits occurred between 5 July and 5 August. Study 5 field crews assessed habitats at random points between 5 April and 4 August.

Study 3 field personnel assessed physical habitat features ocularly within 50 m and 100 m of nests and random points. Variables included number of rock outcrops, vegetative cover classes, presence of hills and buttes (with slopes >15%), presence of agricultural development, artificial perches, artificial nest structures, and roads. We also assessed the presence of agricultural development (defined as any irrigated land, including irrigated pasture) and described vegetative cover types within a 500-m radius of the nest and random point. Slope of hills and buttes was measured with a clinometer or estimated visually. We described vegetative cover classes as "open" or "closed." Open cover types had low vegetation (e.g., grasses) or lacked vegetative cover within ≥50% of the prescribed radius. Closed cover types had shrubs covering ≥50% of the prescribed radius.

Habitat characteristics obtained from the Digitized Resource Data Base Map (DRDBM) included grazing regime type, soil depth, soil development, and landform. Grazing seasons were either spring-fall (north of the drift fence) or winter 9south of the drift fence). We obtained soils data from Ada, Canyon, Elmore, and Owyhee County soil surveys (U.S. Dep. Agric. 1972, 1980, 1991, unpubl.). Soil depth was analyzed for 3 categories: shallow (<51 cm), medium (51-102 cm), and deep (>102 cm). Landform was classed as "basaltic" or "other soil type," and soil development was considered either "strong" or "weak." We also calculated the proportion of each military regime within a 1-km radius of each nest or random point. We defined military regimes as (1) artillery position areas, (2) tracking areas, (3) inside the Impact Area, and (4) non-military (outside the OTA).

As in 1993, habitat variables obtained during transect surveys at nesting areas and random points included percent vegetative cover, percent shrub cover, mean shrub height (in cm), species richness (number of plant species), plant species diversity index ($1/\Sigma\ p_i^2$ where p_i was the proportion of the i_{th} species in the sample; Hill 1973), and the presence of cow and sheep sign and tank tracks. In 1994, we also estimated minimum canopy height of shrubs and shrub density for the first time. At nesting areas and random points, we sampled habitat characteristics along a single 5 x 400-m strip transect and 7 50-m lateral transects perpendicular to the 400-m center line. At nesting areas, the nest or centroid of a nesting area where the nest was not found represented the midpoint of the 400-m transect. At Study 5 sites, the random point and starting point of the 400-m transect were the same. Percent vegetative cover, percent shrub cover, species richness, and the diversity index were estimated from point frames along the lateral transects. We positioned a point frame along each lateral 5 times beginning from a randomly selected starting point. Shrub density, minimum shrub canopy height, and mean shrub height were estimated within 2 circular sampling areas with 2.5-m radii positioned along each lateral transect. Cow and sheep sign were estimated as the number of 4 100-m sections along the 400-m center line on which tracks or fecal material were observed. We estimated tank tracks as the number of sections on which we observed tank tracks. Additional field procedures used to obtain these data were described by Knick (1991).

Nest Distribution in the OTA.--As in 1993, we examined relationships between nest distribution and military activities in the OTA using information on where and when military maneuvers occurred. We considered 2 types of military use: field activities and range activities. Field activities included bivouac sites, artillery firing points, and vehicle use of main roads. We did not analyze tank maneuver areas or tank tracking paths in 1994 because these activities did not occur in the OTA until early August, after the breeding period had ended. Range activities included use of stationary firing ranges along Range Road. Personnel from the Environmental Division of the IDARNG monitored bivouac areas and artillery firing points and recorded dates of use. Coordinates of bivouac sites and firing points were obtained using the Global Positioning System (GPS). To analyze nest distribution and road use, we obtained information on road systems from the GIS. We used only gravel roads (e.g., Pleasant Valley Road, Range Road) and main dirt roads in the analysis. We obtained information about range activities from the IDARNG's Daily Range Log.

To examine relationships between military use and nest distribution, we represented all military use areas, road systems, nests, and random points on the GIS. Military use areas were represented as polygons. We then compared distances between occupied nests and random points and between successful and unsuccessful nests to the nearest road and military polygon. We compared distances within 2 time periods: the pre-incubation period and the incubation/brood-rearing period. We compared distances of nests and random points during pre-incubation to determine if raptors avoid military use areas when establishing nests. Similar distances during incubation and brood-rearing were compared to determine relationships between military use and nest failures.

We compared distances of nests and random points during the pre-incubation period only for burrowing owls and short-eared owls. We found only 1 ferruginous hawk nesting area and no northern harrier nesting areas in the OTA in 1994. All military activities that occurred before the 1994 median egg laying date for short-eared owls (9 April) and for burrowing owls (22 April) were used in the analysis. These comparisons were limited to roads and range activities because military field activities did not begin until mid-May. We compared distances between successful and unsuccessful nests during the brood-rearing period for burrowing owls, short-eared owls, and for all military activities. All comparisons were done using t-tests.

RESULTS

Prairie Falcon Abundance and Reproduction

Abundance.--We identified only 160 prairie falcon pairs in the NCA in 1994, fewer than in any year that complete surveys of the area have been conducted. The count represents a 14% decline from 1993 levels. Numbers of pairs decreased from 1993 levels in 9 10-km stretches, remained the same in 8, and increased in only 2 (Table 1). Although surveys of Unit 26 were incomplete in 1994, it is unlikely that a full survey would have located >2 additional pairs.

Seven 10-k units had prairie falcon densities below levels recorded from 1976-78, and 12 units were unchanged from 1976-78 levels. No stretches of the canyon had more pairs than observed between 1976 and 1978 (Table 1). The sharpest declines from 1993 levels occurred in the OTA shadow (22%). West of the OTA, the number of pairs dropped by 8%, and east of the OTA the counts fell by 14%.

We counted only 57 pairs in the 8 randomly selected stretches, the lowest number ever recorded and well below the 10-year average of 73.7 (Table 2). In units 7, 8, and 15 (the 3 stretches surveyed annually from 1976 through 1984, every other year thereafter until 1988, and every year from 1990-1993), 1994 prairie falcon numbers decreased by 6 to 27 pairs, the lowest total ever recorded (Fig. 1).

The number of falcon pairs per km of canyon was still highest west of the OTA (3.0 pairs/km in units 4 and 5) and lowest east of the OTA (1.0 pairs/km in units 11, 12, and 13). The 40-km OTA shadow (units 6, 7, 8, and 9) had intermediate densities with 1.23 pairs/km. The difference in densities was not as great when viewed in relation to the cliff area in

Table 1. Number of prairie falcon pairs by 10-km unit, 1990-94.

10-km Unit	1990	1991	1992	1993	1994	Change from 1993	Change from 1976-78[a]
03	1	1	1	0	0	0	0
04	20	20	23	23	21	-	-
05	41	48	41	42	39	-	0
06	32	31	32	30	23	-	-
07	15	14	13	14	8	-	-
08	13	6	12	12	12	0	0
09	5	6	7	7	6	-	0
10	2	3	2	3	3	0	-
11	1	2	1	1	1	0	-
12	15	12	17	17	12	-	0
13	19	19	19	17	17	0	-
15	10	8	10	7	7	0	-
16	1	1	1	1	3	+	0
17	0	0	0	1	0	-	0
24	3	6	7	6	2	-	0
25	2	1	2	2	1	-	0
26[b]	3	3	3	2	3	+	0
35	0	0	1	0	0	0	0
37	2	2	2	2	2	0	0
Total	185	183	194	187	160	-	-

[a] 0 = within the 1976-78 range
- = lower than the 1976-78 range
+ = higher than the 1976-78 range

[b] surveys of unit 26 were incomplete in 1994.

each stretch. The number of pairs per km^2 of cliff was still lowest east of the OTA (0.026), highest west of the OTA (0.039), and intermediate in the OTA shadow (0.032).

Reproduction.--Of 214 preselected and back-up nesting areas monitored by Study 2 and 3 during the 1994 nesting season, 112 (52%) were occupied by prairie falcon nesting pairs. In addition, 1 preselect ed nesting area (Petroglyphs) was occupied by an unpaired female. Occupancy rates were highest west of the OTA where 39 of 60 historical nesting areas (65%) were occupied. Occupancy rates were similar (64%) east of the OTA, but fewer than half of all historical nesting areas were occupied east of the ISA (37%) and in the OTA shadow (46%).Control pairs had a 61% nesting success rate, higher than that observed in 1993, but lower than the long-term average of 66% (Table 3). Thirty-four pairs bred successfully, 9 breeding pairs were unsuccessful, and breeding was not confirmed for 13 unsuccessful pairs. Successful control pairs fledged an average of 4.44 young, the highest average brood size at fledging ever recorded in the NCA (Table 3). This yielded an estimated 2.71 young fledged per pair, higher than the long-term mean productivity rate of 2.55 young/pair/year.

Table 2. Number of occupied prairie falcon nesting areas in randomly selected 10-km units in the NCA.

10-km Unit	1976	1977	1978	1986	1988	1990	1991	1992	1993	1994	$\bar{x}$
3	0	0	1	0	1	1	1	1	0	0	0.5
6	32	32	30	23[a]	28	32	31	32	30	23	29.3
7	13	12	14	12	10	15	14	13	14	8	12.5
8	13	12	9	10	16	13	6	12	12	12	11.5
15	13	13	12	13	13	10	8	10	7	7	10.6
24	3	4	2	2	4	3	6	7	6	2	3.9
26[b]	4	5	3	1	4	3	3	3	2	3	3.1
37	3	3	2	3	2	2	2	2	2	2	2.3
Total	81	81	73	64	78	79	71	80	73	57	73.7

[a]Surveys of the south side of the river between the mouth of Sinker Creek and Balls Line West may have been incomplete in 1986.
[b]Surveys of unit 26 were incomplete in 1994.

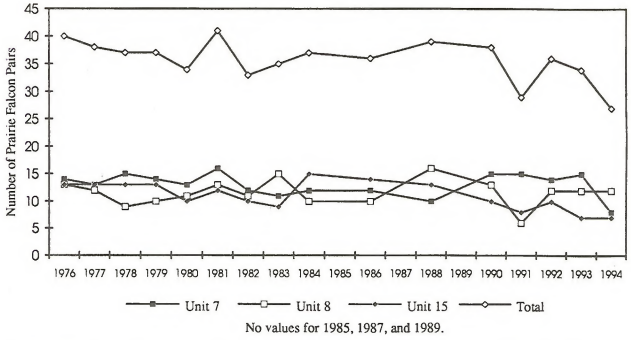

Fig. 1. Number of occupied prairie falcon nesting areas in 10-km survey units 7, 8, and 15 in the NCA.

Breeding attempts were confirmed during incubation at 29 of the 56 occupied control nesting areas, and 20 of these pairs (69%) were successful (Table 3). Number of young fledged per attempt was 3.06, higher than the 21-year mean of 2.82 (Table 3). Success rates of control nesting pairs in the ISA did not differ from those of pairs radioed in 1994 (59% and 61%; G_1 =0.02; $P > 0.10$). In 1994, 53% of pairs nesting within the OTA shadow successfully raised young, compared to 63% of pairs east and west of the shadow, but differences were not statistically significant (G_1 =0.87; $P > 0.10$). Mean number of young fledged per successful pair in the shadow was 0.52 chicks lower in the shadow than east and west of the shadow (3.94 vs. 4.46 young per successful pair), and the difference approached statistical significance (ANOVA $F_1 = 3.14$, $P = 0.09$).

Golden Eagle Abundance and Reproduction

Abundance.--In 1994, golden eagle pairs occupied 30 (77%) of the 39 preselected nesting areas in the NCA and 21 (88%) of the 24 preselected nesting areas in the Comparison Area. The number of occupied nesting areas in the NCA was 1 more than in 1991 and 1993; the same as in 1992; and 3 fewer than in 1973, 1974, and 1976 (Table 4). Number of pairs varied from 33 to 35 between 1971 and 1977, then dropped and fluctuated from 28 to 32 between 1978 and 1988. Since 1989, the number of pairs has held steady at 29 to 30, down 5 or 6 from the early 1970's. A linear regression showed that number of eagle pairs has declined significantly from 1971 to 1994: # pairs = 46.9-0.18*year (r^2 = 0.58, P = 0.003).

Of the 12 vacant nesting areas in the NCA and Comparison Area, 6 have not been occupied since 1982 or earlier. Of these, 4 in the NCA (A-56, Bruneau Bridge, Simpkin, and Bruneau Flats) have been vacant for 12, 14, 16, and 17 years, respectively. In addition, a stretch of canyon that formerly contained 2 adjacent nesting areas (Delates Delight and Pump Station) has been occupied by only 1 pair for the last 17 years. Also, the Grandview Feedlot nesting area appears to have been absorbed by an adjacent pair (Beercase). One vacant nesting area (Swan Dam) was vacant for the sixth consecutive year, and eagles have used the nesting areas associated with the PP&L 125 and PP&L 102 towers only 1 year each. The Strike II nesting area was occupied in 1994 after being vacant for 5 consecutive years.

Reproduction.--Golden eagle reproduction in the NCA declined sharply from 1993 levels (Table 4). Percent of pairs breeding dropped from 90% in 1993 to 63% in 1994. Percent of breeding attempts successful decreased from 80% to 50% between those years. The number of young fledged per successful nesting attempt remained at 1.71, and number of young fledged per pair decreased from 1.23 to 0.54 between 1993 and 1994.

In 1994, productivity (young fledged per pair) in the Comparison Area was higher than in the NCA (Tables 4 and 5). Productivity has been higher in the Comparison Area in 13 of the 16 years when intensive surveys were conducted in the Comparison Area (Tables 4 and 5). No pairs in either the NCA or Comparison Area had 3-chick broods in 1994.

Ferruginous Hawk Abundance and Reproduction

In 1994, 25 (34%) of 74 historical ferruginous hawk nesting areas surveyed in the NCA were occupied (Table 6). These included 8 canyon, 15 bench, and 2 non-ISA nesting areas. Fourteen of 28 non-OTA nesting areas (50%) were occupied, but only 1 of 8 OTA nesting areas (12%) were occupied. Two new occupied nesting areas were found on the bench in 1994.

We confirmed 21 breeding attempts at 20 nesting areas (Table 7). These included 5 canyon, 13 bench, and 2 non-ISA nesting areas. We confirmed 14 (67%) of the breeding attempts during incubation: 4 in the canyon, 8 on the bench, and 2 outside the ISA. Of these only 8 (57%) were successful: 1 non-ISA and 7 ISA nesting areas. Cause of failure was unknown for 4 of the 6 unsuccessful breeding attempts. The death of 1 adult probably contributed to 1 nesting failure, and human disturbance during incubation probably caused another nest failure.

Table 3. Nesting success and productivity of prairie falcons in the NCA, 1974-94. Sample sizes are in parentheses.

Year	% of Pairs Successful	% of Attempts Successful	# Fledged/ Successful Attempt	# Fledged/ Attempt [a]	# Fledged/ Pair [b]
1974	73% (15)	64% (11)	3.94 (17)	2.52	2.88
1975	83% (23)	86% (21)	3.74 (27)	3.21	3.10
1976	74% (23)	79% (29)	4.00 (41)	3.16	2.96
1977	57% (14)	67% (27)	4.08 (25)	2.73	2.33
1978	45% (20)	18% (17)	3.29 (17)	0.59	1.48
1979	70% (40)	75% (32)	3.73 (30)	2.80	2.61
1980	59% (49)	65% (54)	4.03 (36)	2.62	2.38
1981	80% (51)	83% (46)	4.04 (22)	3.35	3.23
1982	46% (26)	69% (26)	3.53 (17)	2.44	1.62
1983	71% (31)	73% (26)	3.24 (17)	2.36	2.30
1984	--- ---	88% (16)	3.95 (19)	3.48	---
1985	--- ---	93% (14)	4.08 (13)	3.79	---
1986	--- ---	44% (18)	3.43 (7)	1.51	---
1987	--- ---	72% (36)	4.32 (31)	3.11	---
1988	--- ---	78% (9)	3.86 (7)	3.01	---
1989	--- ---	83% (6)	3.67 (6)	3.05	---
1990	--- ---	74% (19)	4.06 (18)	3.00	---
1991	81% (42)	94% (16)	4.08 (24)	3.84	3.11
1992	75% (56)	85% (34)	4.17 (30)	3.54	3.13
1993	45% (60)	52% (27)	4.05 (22)	2.11	1.82
1994	61% (56)	69% (29)	4.44 (27)	3.06	2.71
$\bar{x}$ All Years	66% SD = 14%	72% SD = 18%	3.89 SD = 0.32	2.82 SD = 0.76	2.55 SD = 0.58

[a]Calculated as the product of % attempts successful and # fledged/successful attempt.

[b]Calculated as the product of % of pairs successful and # fledged/successful attempt. Data are not available for 1984-90 because prairie falcon pairs were not preselected in those years.

Table 4. Nesting success and productivity of golden eagles in the NCA[a], 1971-94. Sample sizes are in parentheses.

Year	# Occupied Nesting Areas	% of Pairs Breeding	% of Attempts Successful	# Fledged/ Successful Attempt	# Fledged/ Pair[b]	Total Fledged
1971	34	100% (31)	62% (21)	1.89 (19)	1.17	40
1972	34	---- ----	---- ----	1.64 (11)	----	----
1973	35	65% (34)	44% (18)	1.38 (8)	0.40	14
1974	35	67% (33)	53% (17)	1.50 (10)	0.53	19
1975	33	75% (32)	56% (18)	1.45 (11)	0.61	20
1976	35	68% (34)	50% (16)	1.60 (10)	0.54	19
1977	34	82% (34)	59% (17)	1.50 (10)	0.73	25
1978	32	75% (32)	77% (13)	1.70 (10)	0.98	31
1979	30	97% (30)	63% (24)	1.40 (15)	0.86	26
1980	31	87% (31)	76% (21)	1.78 (18)	1.18	37
1981	30	100% (30)	73% (22)	1.74 (19)	1.27	38
1982	30	87% (30)	79% (24)	2.00 (18)	1.38	41
1983	28	96% (27)	67% (18)	1.57 (14)	1.01	28
1984	31	---- ----	59% (17)	1.56 (9)	0.64[c]	20
1985	32	38% (32)	42% (12)	1.00 (4)	0.16	5
1986	29	55% (29)	40% (14)	1.20 (5)	0.26	8
1987	32	78% (32)	32% (25)	1.38 (8)	0.34	11
1988	32	74% (31)	52% (23)	1.54 (13)	0.59	19
1989	30	80% (30)	63% (19)	1.36 (14)	0.69	21
1990	30	87% (30)	80% (25)	1.65 (20)	1.15	34
1991	29	90% (29)	74% (23)	1.59 (17)	1.06	31
1992	30	86% (29)	56% (16)	1.73 (11)	0.83	25
1993	29	90% (29)	80% (15)	1.71 (14)	1.23	36
1994	30	63% (30)	50% (12)	1.71 (7)	0.54	16
$\bar{x}$	31.5	79%	60%	1.57	0.79	25
SD	2.1	15.5	13.9	0.22	0.35	10.3
CV	6.6	19.6	23.2	14.0	44.3	41.2

[a]Includes the Walters Butte territory.
[b]Based on % of pairs breeding, % of attempts successful, and # fledged/successful attempt.
[c]Based on % of pairs successful and # fledged/successful attempt.

Table 5. Nesting success and productivity of golden eagles in the Comparison Area, 1971-94. Sample sizes are in parentheses.

Year	% of Pairs Breeding	% of Attempts Successful	# Fledged/ Successful Attempt	# Fledged Per Pair
1971	100%(22)	44%(16)	1.54 (13)	0.67
.	.	.	.	.
1973	43%(21)	88%(8)	1.38 (8)	0.52
1974	47%(19)	75%(8)	1.50 (6)	0.53
1975	83%(18)	60%(10)	1.43 (7)	0.71
1976	74%(19)	83%(6)	1.56 (9)	0.96
1977	89%(18)	60%(5)	1.89 (9)	1.01
1978	68%(22)	64%(14)	1.89 (9)	0.82
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
1986	58%(19)	67%(9)	1.43 (7)	0.56
1987	94%(18)	44%(18)	1.14 (7)	0.47
1988	95%(20)	71%(17)	1.50 (14)	1.01
1989	84%(19)	63%(16)	1.50 (10)	0.79
1990	89%(19)	59%(17)	1.64 (11)	0.86
1991	95%(19)	85%(13)	2.00 (13)	1.62
1992	95%(21)	63%(16)	1.73 (11)	1.04
1993	85%(20)	71%(17)	2.09 (11)	1.26
1994	76%(21)	88%(16)	1.38 (13)	0.92
$\bar{x}$	80%	68%	1.60	0.86
SD	18	14	0.26	0.31

Table 6. Number of occupied historical ferruginous hawk nesting areas in the NCA, 1994. Numbers in parentheses are sample sizes[a].

Area	# Historical Areas Surveyed	% Historical Nesting Areas Occupied
Canyon	31	26% (8)
Bench	36	42% (15)
Non-ISA	7	28% (2)
NCA	74	34% (25)

[a] Based on preselected nesting areas.

successful were similar to 1993 values, but the number of young fledged per pair (1.88) was the highest recorded since surveys began in 1977. However, we did not confirm brood counts at 2 successful nesting areas and excluded these sites from the analysis. At 1 nesting area, we suspect only 1 nestling fledged. If this site is included in the analysis, young fledged per pair drops to 1.74, the 1980 value. The percent of pairs successful (35%) was the lowest since 1978.

Nesting of Raptors on the Benchlands

General Survey Results.--In 1994, we located 151 occupied raptor nesting areas on the ISA benchlands (Table 9), 45 more than in 1993. Forty-nine were inside the OTA, and 102 were outside the OTA. These included 18 ferruginous hawk, 11 northern harrier, 87 burrowing owl, and 35 short-eared owl pairs. Fifty-four of the 151 pairs were first located during historical nest surveys, 12 were first located during quadrat surveys, and 85 were found incidentally. We documented renesting for 1 ferruginous hawk and 2 short-eared owl pairs.

On a unit area basis, we found 8.6 nesting areas per 100 km^2 inside the OTA and 7.1 per 100 km^2 outside the OTA. However, 5 ferruginous hawk nesting areas considered outside the OTA for this analysis were on the OTA boundary. If these areas are dropped from the analysis then 6.7 nesting areas per 100 km^2 were found outside the OTA.

In 1994, we determined occupancy at 205 historically occupied nesting areas on the benchlands; 204 of these were preselected. Fifty-eight (28%) of the preselected nesting areas visited were occupied. Ten (18%) of the historical nesting areas inside the OTA were occupied, compared to 48 (33%) of the nesting areas outside the OTA. In 1994, we determined fate at 104 of 106 nesting areas occupied in 1993. Forty-six (44%) of these were reoccupied in 1994.

One of the 18 ferruginous hawk nesting areas on the benchlands (PP&L 109 East) was established in 1994, and 1 (AFB) was first found in 1994. Of 14 ferruginous hawk breeding attempts, 2 were on rock outcrops, 2 were on the ground, 7 were on transmission towers or poles, and 2 were on artificial platforms. The nest for 1 breeding attempt where fledged young were observed (PP&L 111) was not located, but we suspect it was on the ground.

Seven of 11 occupied northern harrier nesting areas in the ISA benchlands had not been previously recorded and were found incidentally. One of these nesting areas was in a wheat field, 1 was in a fallow field, 3 were in tall tumblemustard (*Sisymbrium altissimum*), and 1 was in a creek bed lined with cattails (*Typha latifolia*). The seventh nest was not located but was in either a riparian area or an alfalfa field.

Thirty-one of 35 occupied short-eared owl nesting areas on the ISA benchlands had not been previously recorded. We found 5 nesting areas during quadrat surveys, 4 during historical checks, and 26 incidentally. We confirmed 26 breeding attempts at 24 nesting areas, but found only 15 nests. We found both nests at 1 nesting area where

Table 7. Nesting success of ferruginous hawks in the NCA, 1994. Sample sizes are in parentheses.

Area	# Breeding Attempts[a]	% Breeding Attempts CDI[b]	% Attempts Successful CDI[b]
Canyon	5	80 (4)	0
Bench	14	57 (8)	88
Non-ISA	2	100 (2)	50
NCA	21	67 (14)	57

[a]With known outcomes.
[b]CDI = confirmed during incubation.

Table 8. Nesting success and productivity of ferruginous hawks in the NCA, 1977-94. Sample sizes in parentheses.

Year	% of Pairs Breeding	% Attempts Successful	Young/Successful Attempt	% Pairs Successful[a]	# Fledged per pair[b]
1977	92 (12)	27 (11)	1.50 (2)	25 (12)	0.37
1978	83 (12)	43 (7)	3.00 (4)	33 (12)	1.07
1979	60 (15)	67 (9)	2.83 (6)	40 (15)	1.14
1980	70 (17)	92 (12)	2.70 (10)	65 (17)	1.76
1981	100 (6)	62 (8)	2.80 (5)	71 (7)	1.74
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
1985	95 (20)	56 (25)	2.67 (12)	52 (21)	1.42
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
1992	95 (21)	33 (15)	2.80 (5)	44 (23)	0.88
1993	84 (19)	58 (12)	3.00 (10)	46 (24)	1.46
1994	85 (20)	57 (14)	3.89 (9)	35 (23)	1.88

[a]Based on preselected pairs.
[b]Based on % of pairs laying eggs, % of attempts successful, and # fledged/successful attempt.

Table 9. Number of occupied raptor nesting areas found on ISA benchlands in 1994 using different survey methods. Numbers in parentheses indicate percent of nesting areas first located by each method.

Survey Type	Ferruginous Hawk	Northern Harrier	Burrowing Owl	Short-Eared Owl	Totals
Historical	4 (78)	4 (36)	32 (37)	4 (12)	54 (36)[a]
Quadrat	1 (5)	0	6 (7)	5 (14)	12 (8)[b]
Incidental	3 (17)	7 (64)	49 (56)	26 (74)	85 (56)
Totals	18	11	87	35	151

[a]Fifty-nine historical nesting areas were occupied, but 5 were found during quadrat surveys or incidentally.
[b]Nineteen nesting areas were found during quadrat surveys, but only 12 were first located by that method.

renesting occurred. Four nests were in patches of dead Russian thistle (*Salsola iberica*), 4 were in grass and forb patches, 3 were in patches of dead, standing tumblemustard, and 4 were placed next to or under a shrub. Two nests were under or near green rabbitbrush (*Chrysothamus viscidiflorus*), and 2 nests were under or near big sagebrush (*Artemisia tridentata*).

Fifty-two of 87 occupied burrowing owl nesting areas on the ISA benchlands had not been recorded previously. We found 6 nesting areas during quadrat surveys, 32 during historical checks, and 49 incidentally. Thirty of 71 nesting areas occupied in 1993 were reoccupied in 1994. At 15 nesting areas, the same burrow used in 1993 was used again in 1994. One burrow in the Impact Area was excavated on the side of an artificial berm supporting a moving target system. All other nests were in ground-level burrows.

Relative Abundance.--Fifty quadrats (20 inside and 30 outside the OTA) were surveyed twice on ISA benchlands in 1994. Twenty-nine (19.2%) of 151 occupied nesting areas on the benchlands were inside quadrats, but only 19 (12.6%) were detected during quadrat surveys. Fourteen of these were inside the OTA, and 5 were outside the OTA (Table 10).

Burrowing owls were the most abundant of the 3 species found during quadrat surveys, accounting for 12 of the 19 nesting areas found. We also found 2 ferruginous hawk and 5 short-eared owl nesting areas. We found 0.7 nesting areas per quadrat inside the OTA compared to 0.2 nesting areas outside the OTA. Contingency table analysis of quadrats with and without nesting areas indicate that these differences approached significance (G_1 = 3.124, P =0.08).

We missed 17 nesting areas inside quadrats during the first quadrat survey. Seven of these (1 ferruginous hawk and 6 burrowing owl nesting areas) were found during the second quadrat survey. Pairs at 3 nesting areas failed and vacated their burrows before the second survey. We missed 1 short-eared owl and 5 burrowing owl nesting areas during both quadrat surveys.

The relatively low number of nesting areas detected during quadrat surveys (19 of 151) suggests that raptor nests on the bench are more likely to be encountered incidentally or at historically occupied nesting areas than within random plots. In comparison, we found 54 occupied nesting areas during historical searches and 84 incidentally. A total of 860 hrs of effort was spent during quadrat surveys, or 72 hrs per occupied nesting area. We

Table 10. Number of occupied raptor nesting areas found on ISA benchlands during quadrat surveys.

Species	Inside OTA (n = 20)	Outside OTA (n = 30)	Totals (n = 50)
Ferruginous Hawk	0	2	2
Northern Harrier	0	0	0
Burrowing Owl	9	3	12
Short-eared Owl	5	0	5
Total	14	5	19
Number per Quadrat	0.7	0.17	0.38

spent an average of 8.0 hrs per quadrat inside the OTA and 9.0 hrs per quadrat outside the OTA, but we found nests in only 20 of 50 quadrats. Surveys of 16 quadrats in 1990, 768 transects and circular plots in 1991, 44 quadrats in 1992, and 48 quadrats in 1993 also showed a low return per unit effort for random plot surveys (Lehman et al. 1990, 1992, 1993; Steenhof et al. 1991).

Nesting Success.--In 1994, we confirmed breeding at 114 of 151 occupied nesting areas on ISA benchlands. These included 13 ferruginous hawk, 7 northern harrier, 70 burrowing owl, and 24 short-eared owl nesting areas. Of the 114 nesting areas where breeding was confirmed, 46 were found during incubation. Thirty-six of these were successful, and 10 were unsuccessful.

Of 13 ferruginous hawk nesting areas on the bench where breeding was confirmed, 8 were found during incubation (Table 11). Of these, 7 were successful and 1 failed. Six of 7 non-OTA nesting attempts were successful. Only 1 nesting attempt was in the OTA; it was successful, but it was found after young had hatched.

We found 3 of 7 northern harrier nesting attempts during incubation (Table 11). All of these were outside the OTA and failed during the incubation stage, probably due to predation.Of 26 short-eared owl nesting attempts at 24 nesting areas, only 7 were confirmed during incubation (Table 11). One was successful and 6 failed. One of 2 nesting attempts in the OTA was successful, and all 5 outside the OTA failed. See Rivest (this volume) for causes of nest failures.

Of 86 occupied burrowing owl nesting areas where fate was determined, 69 were successful and 17 were unsuccessful (Table 11). We found 37 of these pairs during incubation or before 20 May. Of these, 28 (76%) were successful and 9 (24%) were unsuccessful. Twelve of 15 nesting areas (80%) inside the OTA were successful compared to 16 of 22 (73%) outside the OTA; however, these differences were not significant (G_1 =0.26, P =0.61).

During mid-June we used the MOLE camera system to assess fate at 27 occupied burrowing owl nesting areas. We used the MOLE in 37 burrows. However, the device proved to be too tall to navigate most burrows. We were able to age young at 3 nesting areas and confirmed a failure (due to a collapsed burrow) at 1 nesting area. The MOLE could not access 5 burrows known to have owls in them at the time. It reached the natal chamber (about 3 m inside the burrow) at 2 nesting areas, but the nestlings had already moved to satellite burrows. The device appeared to be about 2 cm too tall for most burrowing owl burrows on the benchlands. We hope to use the system again in 1995 after modifications have been made.

Habitat Assessments. -- We described habitat characteristics at 143 occupied nesting areas and 126 random points. Habitat characteristics were not described at 6 nesting areas because of access problems and time constraints, and at

Table 11. Nesting success of breeding raptors on ISA benchlands.

	Successful Nesting Areas		Unsuccessful Nesting Areas		
	Found During Inc.	Found After Inc.	Found During Inc.	Found After Inc.	Totals
Ferruginous Hawk	7	3	1	3[a]	14
Northern Harrier	0	4	3	0	7
Burrowing Owl	28	41	9	8[b]	86
Short-eared Owl	1	16[a]	6	2	25
Totals	36	64	19	13	132

[a] includes renests.
[b] breeding attempts were not confimed at these unsuccessful nesting areas.

l nesting area because it was found after young had dispersed. In the analysis, we excluded 16 of the 143 nesting areas surveyed because >25% of the sampling area consisted of irrigated agriculture at 14 sites, and because 2 nesting areas burned in wild fires before habitat data were collected. We excluded nesting areas near agriculture because irrigated fields artificially inflated or lowered continuous variables relating to vegetative cover, species richness, and diversity. However, we analyzed nest distribution in relation to agriculture using a set of categorical variables (see below).

G-tests involving 19 categorical variables revealed significant differences between nesting areas and random points (Table 12). Nesting areas were more likely than random points to be within 100 m of roads, artificial perches, and artificial nest structures, and to be within 500 m of agricultural developments. Nesting areas were also more likely to be in areas of open vegetation (<50% shrub cover) than random points. Nesting areas also were on medium to deep soils more often than random points. The tendency of nesting areas to be nearer roads than random points probably indicates a survey bias rather than a preference by raptors for such locations.

Nesting areas were less likely to be within 100 m of hills or buttes than random points. Also, fewer nesting areas were north of the drift fence (spring-fall grazing) than random points. Variables not important in discriminating between the 2 groups included landform (basalt or other) and soil development (weak or strong).

Separate analyses by species showed that differences in the occurrence of hills near nests and random points were significant only for burrowing owls, although the sample size for northern harriers was too low for statistical analysis. Only 12% of burrowing owl nests were within 100 m of hills and buttes compared to 27% for random points (G_1 = 6.68, P = 0.01). The occurrence of nests near artificial nest structures and perches was significant for short-eared owls (G_1 = 5.16, P = 0.03), but more so for ferruginous hawks (G_1's > 6.93, P's < 0.008). Burrowing owl and ferruginous hawk nests were within 100 m of roads more often than random points (G_1's > 4.67, P's < 0.03). The tendency to nest north of the drift fence was significant only for burrowing owls (G_1 = 7.84, P = 0.005); however, both burrowing owls and short-eared owls tended to nest in open habitat types (G_1's > 5.27, P's < 0.02).

All species except the ferruginous hawk showed tendencies to nest near agricultural developments. Seven of 11 northern harrier nesting areas were within 500 m of irrigated fields or pastures. The occurrence of nests within 500 m of agriculture was statistically significant for the burrowing owl (G_1 = 10.01, P = 0.01) and short-eared owl (G_1 = 5.00, P = 0.02). For the burrowing owl, this was partly because a colony of 13 pairs near Grandview was within 200 m of an irrigated field.

T-tests involving 16 continuous variables revealed significant differences between nesting areas and random points in 6 vegetation categories for all species pooled. Species richness was significantly lower at random points than at nesting areas ($\bar{x}$ = 5.1, $\bar{x}$ = 6.9, t_{251} = 6.83, P < 0.001). Percent vegetative cover was lower at nesting areas, and the difference approached significance ($\bar{x}$ = 30.3, $\bar{x}$ = 33.1, t_{251} = 1.80, P = 0.07). Percent vegetative cover at nests and random points in 1994 was only about one-half of that measured in 1993 (1993: $\bar{x}$ = 66.3, $\bar{x}$= 57.4). The differences between the 2 years is probably due to differences in rainfall. Heavy spring rains in 1993 resulted in dense growth of grasses and forbs in the ISA. In 1994, very little rain fell during the spring or summer. In 1993, vegetative cover was significantly higher at nesting areas than at random points (t_{200} = 3.71, P < 0.001), the opposite of that observed in 1994.

At nesting areas and random points with shrub communities, we found significant differences in 4 shrub categories (44.1% of nesting areas sampled and 28.6% of random points had no shrubs). Percent shrub cover and shrub density were lower at nesting areas than at random points (shrub cover: $\bar{x}$= 6.1%, $\bar{x}$ = 9.4%, t_{159} = 2.77, P = 0.001; density: $\bar{x}$ = 5,880 per ha, $\bar{x}$ = 14,018 per ha, t_{159} = 4.78, P = 0.0001). In contrast, minimum canopy height and mean shrub height were higher at nesting areas than at random points (canopy height: $\bar{x}$ = 6.4 cm, $\bar{x}$ = 4.3 m, t_{159} = 2.55, P =0.012; mean shrub height: $\bar{x}$ = 31 cm, $\bar{x}$ = 21 cm, t_{159} = 4.33, P = 0.0001).

T-tests on continuous variables also revealed significant differences in 2 land use categories. Nesting areas showed less cow and sheep sign than

Table 12. Habitat characteristics at benchland sample points for the categorical variables analyzed in 1994. Percentages indicate the proportion of nesting areas and random points exhibiting each characteristic.

Variable[a]	Nesting Area %	Random Point %	G^b	P
HILLS100	12.6	27	8.4	0.004
AG500	23.6	7.9	12.16	<0.001
PERCH100	36.2	23.8	4.66	0.031
ROADS100	52	37.3	5.53	0.019
ARTS100	19.7	10.3	4.41	0.036
HABCV50	90.5	74.6	11.54	0.001
HABCV100	88.9	71.4	12.63	<0.001
HABCV500	84.2	70.6	6.8	0.009
GRAZING	59.8	72.2	4.34	0.037
SOIL DEPTH	84.9	78.4	6.75	0.034

[a] HILLS100 = presence of hills within 100 m; AG500 = presence of agricultural development within 500 m; PERCH100 = presence of artificial perches within 100 m; ROADS100 = presence of roads within 100 m; ARTS100 = presence of artificial nest structures within 100 m; HABCV50, HABCV100, and HABCV500 = open (≥50% of the prescribed radius had no, or low, vegetation cover) or closed (≥50% of the prescribed radius had shrub cover); GRAZING = north or south of the drift fence (values shown are for north of the fence = spring - fall range); SOIL DEPTH = shallow, medium, deep (values shown are for medium and deep combined).

[b] Degrees of freedom = 2 for SOIL DEPTH. For all other variables degrees of freedom = 1.

random points (cow sign: $\bar{x}$ = 2.8 sections with sign, $\bar{x}$= 3.3 sections with sign, $t_{251} = 2.57$, $P = 0.01$; sheep sign: $\bar{x}$ = 0.39 sections with sign, $\bar{x}$ = 0.69 sections with sign, $t_{251} = 1.92$, $P = 0.05$).

Continuous variables not useful in discriminating between nesting areas and random points were the number of rock outcrops, the plant species diversity index, presence of tank tracks, and proportion of the area in various military regimes (tracking areas, firing areas, impact area, and outside the OTA).

When analyzed by species, we found significant differences in 5 vegetation categories. Percent shrub cover and shrub density were lower at nests than at random points for both burrowing owls and short-eared owls (shrub cover: $\bar{x}$ = 6.4% vs. 9.4%, $t_{139} = 2.29$, $P = 0.02$ for burrowing owls, $\bar{x}$ = 4.6% vs. 9.4%, $t_{18} = 2.95$, $P = 0.0008$ for short-eared owls; shrub density: $\bar{x}$ = 6,375 per ha vs. 14,018 per ha, $t_{138} = 4.07$, $P = 0.0001$ for burrowing owls; $\bar{x}$ = 4,192 per ha vs. 14,018 per ha, $t_{57} = 5.51$, P = 0.0001 for short-eared owls). In contrast, mean shrub height was higher at burrowing owl and short-eared owl nesting areas than at random points (for burrowing owls: $\bar{x}$ = 30 cm vs. 22 cm, $t_{139} = 3.18$, $P = 0.002$; for short-eared owls: $\bar{x}$ = 38 cm vs. 22 cm, $t_{98} = 3.27$, $P = 0.001$). Minimum canopy height was also higher at short-eared owl nesting areas than at random points ($\bar{x}$ = 9 cm vs 4 cm, $t_{98} = 2.61$, $P = 0.01$). Species richness was lower at nests than at random points for ferruginous hawks, burrowing owls, and short-eared owls (t_{98}'s > 3.18, P's < 0.002).

Analysis by species also showed differences in 3 land use categories. Ferruginous hawk nests occurred in areas with fewer tank tracks and sheep sign compared to random points (tanks: $\bar{x} = 0.3$ vs. 1.3 sections with tracks, $t_{33} = 3.58$, $P = 0.001$; sheep: $\bar{x} = 0.1$ vs. 0.7 sections with sign, $t_{96} = 3.73$, $P = 0.0003$). Short-eared owl nests also occurred in areas with less sheep sign than random points ($\bar{x} = 0.2$ vs. 0.7 sections with sign, $t_{96} = 3.73$, $P = 0.0003$). Finally, burrowing owl nests were found in areas with less cow sign than random points ($\bar{x} = 2.8$ vs. 3.3 sections with sign, $t_{145} = 2.23$, $P = 0.03$).

Among categorical variables, comparisons of successful and unsuccessful pairs for all species pooled showed only 1 significant relationship. Fewer successful pairs (5.8%) nested within 50 m of hills and buttes than unsuccessful pairs (20.1%) ($G_1 = 4.74$, $P = 0.03$). No continuous variables showed significant differences between successful and unsuccessful pairs when all species were pooled. When we analyzed data by species, we found significant differences only in the plant species diversity index for ferruginous hawks. The index was higher at successful nests than at unsuccessful nests ($\bar{x} = 2.84$, $\bar{x} = 1.7$, $t_{12} = 3.67$, $P = 0.003$).

We found a number of significant differences in the relative occurrence of habitat features inside and outside the OTA. Only 1.7% of random points inside the OTA were within 500 m of agricultural developments compared to 13.2% of random points outside the OTA ($G_1 = 6.60$, $P = 0.01$). Also, random points outside the OTA were more likely to have artificial perches within 100 m than those inside the OTA ($G_1 = 4.18$, $P = 0.04$). Not surprisingly, more tank tracks were found at random points inside the OTA than outside ($\bar{x} = 0.08$ sections with tracks vs. 2.6 sections, $t_{124} = 1.80$, $P = 0.0001$). The OTA also had more rock outcrops (0.38 per random plot inside the OTA compared to 0.08 outside the OTA, $t_{124} = 2.53$, $P = 0.01$). Finally, shrub characteristics at random points inside and outside the OTA differed significantly for minimum canopy height and mean shrub height. In both cases, heights were greater outside the OTA than inside the OTA (canopy height: $\bar{x} = 6$ cm, $\bar{x} = 2$, $t_{53} = 2.77$, $P = 0.0001$; mean shrub height $\bar{x} = 27$ cm, $\bar{x} = 15$, $t_{59} = 4.78$, $P = 0.0002$).

Nest Distribution in the OTA.--In 1994, burrowing owl nests were significantly closer to major roads and firing ranges than random points (roads: $\bar{x} = 816$ m, $\bar{x} = 1{,}778$ m, $t_{85} = 4.42$, $P = 0.0001$; firing ranges: $\bar{x} = 3{,}210$ m, $\bar{x} = 5{,}022$ m, $t_{85} = 3.41$, $P = 0.001$). This may be due to the fact that we were more likely to find nests along roads; also, all ranges in the OTA are on Range Road. Distances of successful burrowing owl pairs to bivouac sites and artillery firing points (military polygons), roads, and firing ranges did not differ significantly from those of unsuccessful pairs (polygons: $\bar{x} = 935$ m, $\bar{x} = 1{,}071$, $t_{30} = 0.36$, $P = 0.72$; roads: $\bar{x} = 865$ m, $\bar{x} = 709$, $t_{30} = 0.40$, $P = 0.69$; firing ranges $\bar{x} = 4{,}295$ m, $\bar{x} = 2{,}684$, $t_{30} = 1.20$, $P = 0.24$).

In 1994, distances of short-eared owl nests to roads did not differ from those of random points ($\bar{x} = 1{,}539$ m, $\bar{x} = 1{,}778$ m, $t_{71} = 0.61$, $P = 0.55$); however, nests were significantly closer to firing ranges than random points ($\bar{x} = 3{,}054$ m, $\bar{x} = 5{,}022$ m, $t_{51} = 3.76$, $P = 0.0004$). The shorter distances between short-eared owl nests and firing ranges may be partly because we were more likely to find nests near firing ranges. At least 6 reports of short-eared nesting areas were turned in by IDARNG field personnel. Sample sizes for successful and unsuccessful short-eared owl pairs in the OTA were too low for statistical analysis of military effects on nesting success.

In 1993, we suspected military activity was the direct cause of several nesting failures. In 1994, we documented no such direct effects. However, at a short-eared owl nesting area near Wind Butte, 1 of 4 fledgling mortalities may have been caused by a military vehicle. A bird was found crushed about 1.6 km north of its nest site inside the OTA. Three of this bird's siblings fell to predation, and 3 survived to dispersal. In addition, a series of wild fires in late May and early June, caused by artillery fire near Ranges 5 and 6, may have resulted in 2 nesting failures by short-eared owls. In both cases, pairs were observed in mid-May, but nesting success could not be confirmed after the fires occurred. We do not know if these birds laid eggs.

In contrast, a burrowing owl pair that nested near the Range 5-6 fire complex was successful even though the fire probably destroyed a portion of the

pair's home range. Also, a short-eared owl pair nested successfully inside the Artillery Impact Area in 1994. This area is the target zone for all artillery fire in the OTA. These birds are the first raptors detected nesting in this area during this study. Two of 6 nestlings counted on 29 April survived to disperse at this nesting area. We did not determine the fates of the other 4 nestlings seen in April. Finally, a burrowing owl pair that nested near Flagstaff Butte fledged ≥5 young even though the burrow was inside a large bivouac site, and another pair that nested near Christmas Mountain was successful although its nest was within 100 m of a permanent MPRC support facility. In both cases, IDARNG personnel avoided contact with these birds whenever possible (N. Nydegger, IDARNG, pers. commun.).

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Influence of Military Training on the Behavior of Raptors in the Snake River Birds of Prey National Conservation Area

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ANNUAL SUMMARY

*We assessed the potential influences of military training on the ranging habits and foraging behavior of 30 radio-tagged prairie falcons (**Falco mexicanus**), 7 radio-tagged territorial golden eagles (**Aquila chrysaetos**), 5 radio-tagged wintering golden eagles, and all raptors using firing ranges in the Orchard Training Area (OTA) in 1994. As in each of the past 3 years, prairie falcons that nested close to the OTA ranged farther and used a more even distribution of prey items than falcons nesting west of the OTA. However, in contrast to previous years, raptors used the firing ranges infrequently in 1994, and their abundance was not correlated with military activity.*

Many observations in 1993 attributed to reductions in the prey base were not confirmed in 1994, the second successive year of low prey populations. The presence of radio transmitters was not associated with low productivity by golden eagles in 1994, as it was in 1993, suggesting that selective pressures other than food limitation may be important. Comparison of nest sites used by instrumented and control eagles in 1993 suggests that greater exposure to solar radiation at nests with radio-tagged

adults may explain their lower productivity. Likewise, although prairie falcons ranged widely and used many different foods in 1993 and 1994, their productivity was substantially higher in 1994 than in 1993. We suggest that declines in the abundance of nest ectoparasites from 1993 to 1994, in combination with a low population of nesting prairie falcons in 1993, allowed for higher falcon productivity in 1994 despite low prey availability.

The OTA continues to provide important wintering habitat for golden eagles. Adults that use the OTA during the winter migrate from northern Canada and Alaska and occupy distinct, yet undefended, winter ranges. Eagles nesting in the Snake River Birds of Prey National Conservation Area (NCA) rarely use the OTA, regardless of season. These eagles expanded their ranges in the nonbreeding season and used nearly identical areas in each year of the study.

OBJECTIVES:

1. Assess the effects of backpack radio transmitters on the behavior and productivity of prairie falcons and golden eagles.

2. Determine the spatial use patterns of prairie falcons in the Orchard Training Area (OTA) shadow and west of the shadow.

3. Assess the impacts of military training on the ranging habits, nesting behavior, and productivity of prairie falcons.

4. Assess the impacts of military training on the abundance and behavior of raptors using firing ranges in the OTA.

5. Monitor habitat use of resident, adult golden eagles.

6. Monitor habitat use of golden eagles wintering in the OTA.

INTRODUCTION

Study 2 is responsible for assessing the potential influences of military training on the behavior of raptors nesting in the Snake River Birds of Prey National Conservation Area (NCA). 1994 represents the fourth year of intensive research designed to understand if, and how, this training influences the spatial use patterns, foraging behavior, and parental care exhibited by raptors. The objective of this report is to present the results from the 1994 season in comparison with results from the previous 3 years. This is the last year of field research, and detailed summaries of our research will be prepared during 1995. As a result, this report is not designed to be all encompassing, but instead stresses procedures or results new in 1994.

METHODS

Terminology

We use the following terms to reference the space used by prairie falcons in the Snake River Canyon: a *nesting area* is a stretch of cliff where nests are found year after year, but no more than 1 pair has ever bred at 1 time; a *territory* is the cliff and canyon terrain actively defended by a pair in a given year; an *aerie*, *scrape*, or *nest* refers to the actual nest location.

The definitions of the OTA shadow, areas west of the shadow, and areas east of the shadow remain as stated in Marzluff et al. (1992).

Trapping Prairie Falcons

We investigated 76 historical nesting areas for the possibility of trapping prairie falcons in 1994 (46 were from the Study 2 OTA shadow preselected list, and 30 were from the Study 2 west of OTA shadow list). We rejected 46 sites because adults were not present or not exhibiting territorial behavior (n = 32), because other raptors were nesting nearby (n = 3), because the adults did not respond to the trapping methods attempted (n = 9), or because there was no place to safely place traps (n = 2). We set traps during courtship, egg-laying, and incubation in 39 historical nesting areas, and

captured 38 adult prairie falcons in 31 nesting areas during March, April, and May 1994 and 3 adult prairie falcons outside nesting areas in April and May 1994.

Nesting areas selected for trapping were a random sample of all areas previously stratified into 2 categories: those within the OTA shadow and those west of the OTA shadow. Nineteen captures occurred west of the OTA, 19 occurred in the OTA shadow, and 3 occurred outside nesting areas. We placed a radio transmitter (14 - 16 g) on each captured falcon unless we felt eggs in the abdomen or if the individual had been instrumented in a previous year of the study. We instrumented 15 birds in the OTA shadow and 16 birds west of the OTA shadow. One individual, at Slice Draw, shed its transmitter soon after the trapping period, and another site was trapped.

Two teams trapped from 16 March through 17 May 1994. Marzluff et al. (1991, 1992, and 1993) described methods for capturing, measuring, applying radio transmitter backpack packages, and monitoring prairie falcons. We released birds as soon as the attachment was completed. Average handling time was 65.6 min (n = 31, SD = 13.6) for radioed birds. Appendix A lists all band combinations and physical characteristics of all falcons captured in 1994.

Productivity

Field Protocol.--We monitored the breeding status of 27 pairs of prairie falcons (15 west of OTA shadow and 12 OTA shadow) that included at least 1 radio-tagged adult. We could not determine the breeding status of 1 radio-tagged falcon (trapped at Red Trail) that we failed to observe in an historical territory. We observed sites, rappelled to aeries, and measured nestlings as described in Marzluff et al. (1991). We failed to obtain complete fledge counts at 3 sites (Conning Tower Downstream, Halverson Trail, and Ogden Rock) where chicks were inaccessible due to unusually deep or convoluted aeries. We monitored unsuccessful aeries as described in Marzluff et al. (1991). Study 3 monitored the breeding status of 49 pairs of prairie falcons (12 west of OTA shadow, 21 OTA shadow, and 16 east of OTA shadow), but 5 territories (3 west and 2 shadow) with previously radio-tagged adults were dropped from this sample (NBS, unpubl. data) for comparisons of radio effects.

Analysis.--We used a 2-factor (treatment and year) log-linear model to test for the effect of radio-tagging on the success of falcons. We also tested for sex-specific radio-tagging effects (treatment = male instrumented or female instrumented) on falcon breeding success using a 2-factor (treatment and year) log-linear model.

To determine the effects of radio-tagging on prairie falcon productivity in the 4 years of study, we used a 2-factor (year and treatment) ANOVA to analyze the number of fledglings produced by successful pairs with and without a radio-tagged adult. We did not analyze the number of fledglings produced by all pairs for treatment differences, because the large number of broods with 0, 4, or 5 chicks produced non-normal data that replicated the success/fail categorical data. We further analyzed the productivity of radio-tagged falcons using a 2-factor (year and treatment) ANOVA to compare the number of fledglings produced by radio-tagged males versus the number produced by radio-tagged females.

We analyzed behavioral differences between radio-tagged and control falcons using a 2-factor (year and treatment) ANOVA with 1 repeated measure (nestling stage). We transformed percentages (arcsine of their square root) prior to analysis.

We compared weights of nestlings raised by control and radio-tagged pairs of prairie falcons using a 2-factor (year and treatment) ANOVA with seventh primary, footpad length, and brood size as covariates. Before analysis, we separated fledglings into large (female) and small (male) groups based on footpad lengths >86 mm and <86 mm, and adjusted the weights for fullness of crop (NBS, unpublished data). To reduce the dependency of the data, weights used in the analysis were the mean weight per sex within each brood.

Radio Telemetry

Field Protocol.--Radio tracking procedure in 1994 was the same as used in 1993 (Marzluff et al. 1993). The number of days sampled per zone was: Zone OTA1= 9, OTA2 = 8, W1 = 9, W2 = 9, W3 = 10,

W4 = 12, W5 = 8, W6 = 9 (see Marzluff et al. 1992, Fig. 1 for location of zones).

Collection of Weather Data.--We obtained weather data from Weather Wizard® stations placed at 3 sites: the MPRC Tower on Christmas Mountain, the MATES building on Orchard Road, and at Swan Falls Dam. The sites were 20 m and 10 m and 3 m from the ground, respectively. Temperature sensors at all sites were shielded from direct sunlight. We used weather data from Christmas Mountain for radio-tracking analyses; when the station failed, we used data from MATES. Weather data (average temperature, maximum temperature, average wind speed, maximum wind speed, and wind direction) were collected continuously and stored every half-hour.

Use of Beacons to Test Accuracy of System.--As in previous years, we took fixes on transmitters at known locations to check the accuracy and precision of our remote estimates. This year, however, we designed beacon testing to more closely represent tracking actual falcons. To simulate transmitter signal absorption by the body of a falcon, we attached the beacon transmitter to a road-killed black-crowned night heron (*Nycticorax nycticorax*) using the same attachment as used on falcons. This beacon was elevated to a height of 2.5 m during testing, and moved in and out of tracking zones while 6 trackers triangulated on it. In the past, testing occurred with fewer trackers, and the beacon tended to stay within the zone. Beacon testing took place during March.

Direct Observations of Prairie Falcons.--As in 1993, we visually monitored radio-tagged falcons to check our ability to estimate location by remote telemetry. Falcons were monitored 1-3 times per week by 1 observer. Instead of following predetermined individuals as we did in 1993, we worked closely with the radio-tracking team to find falcons they were tracking. When trackers obtained a remote fix on a falcon, the observer tried to locate it with hand-held telemetry, a global-positioning system (GPS), and binoculars. If the falcon was visually located, additional fixes were taken by the radio-trackers. We surveyed all visually-confirmed locations of falcons with a GPS and then compared to the remote-telemetry estimate. For analysis, we divided direct observations into 2 categories based on accuracy of observed location: "known" for when falcons were perched on a physical object that could be accurately located with a GPS, and "estimated" for when the falcon was flying and its location was determined with less precision.

Analyses.--The selection of "acceptable" fixes is central to home range analyses. In past years we accepted a fix if the estimated error ellipse associated with it was <1000 ha (Marzluff et al. 1991, 1992, 1993). As discussed by Marzluff et al. (1993), the size of the error ellipse was a poor indicator of the accuracy of a fix; therefore, we developed a regression model to predict the linear error of a fix and thus distinguish the most accurate and precise fixes. We accepted all fixes with estimated errors smaller than the upper 75% quartile hinge of the distribution of errors within years. The method resulted in substantially more "acceptable" fixes per bird than in previous years. We reanalyzed all previous data using the new selection method.

We examined falcon spatial use patterns in 3 ways: (1) mean and maximum distance travelled from the nest by successful and failed breeders; (2) "outer" ranges with minimum convex polygons and 95% harmonic mean ranges for all birds (successful, failed, and non-nesters); and (3) "inner" ranges with 50% convex polygons and 50% harmonic mean ranges. We used only adequately sampled falcons (males with >40 fixes and females with >25 fixes; Marzluff et al. 1992) in analyses.

In previous years, we used contacts (the signal was received from a given site) and fixes (the site participated in a fix) from selected receiver sites as indicators of falcon activity in and out of the OTA. We assumed that a falcon must be relatively close to a site for that site to participate in a fix. However, under our new definition of a "good" fix, this assumption was no longer true. Rather than count all fixes in which a site participated, we counted only fixes whose estimated locations were <3 km from the selected site. The 3-km limit was chosen because no selected site was <3 km of either the OTA boundary or each other. The use of contacts remains the same as in previous years.

To determine falcon use of the OTA, we used a Geographical Information System (GIS) to overlay

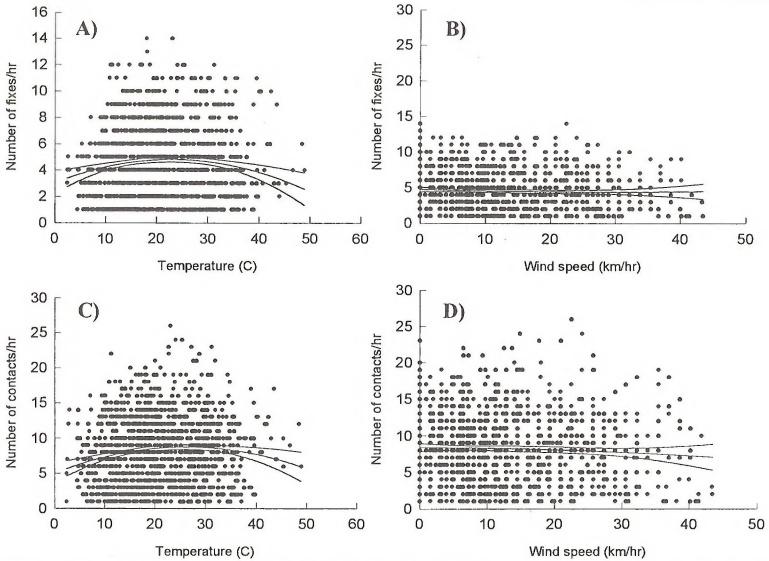


Fig. 1. Relationship between temperature and wind speed, and the number of falcons within 3 km of a site (A, B) and the number of falcons contacted per site (C, D). Least squares estimated regression lines with associated 95% confidence intervals are plotted through points.

falcon fixes on maps of the OTA and Range Road. We classified fixes as inside the Range Road, outside the Range Road but within the OTA, or outside the OTA. We then calculated the percentage of fixes on each falcon that occurred in each area.

We examined the influence of military activity on falcon activity using the same method described in Marzluff et al. (1993). Because our fix-selection criteria have changed, data from past years were recalculated.

Behavior of Prairie Falcons in Territories

Field Protocol.--We monitored 12 instrumented falcons and 1 non-instrumented falcon (Sand Rock) in their territories from 3 May to 23 June 1994 to determine parental attendance and prey handling rates. Five of the territories were within the OTA shadow, and 8 were west of the OTA shadow (Table 1). We watched each territory for an average of 70 hr (range = 14.8 - 126 hr) over an average of 4.5 days (range = 2 - 8 days) from blinds placed to optimize our view of the scrape and to minimize disturbance. We set up blinds for the entire field season at all territories except 3 sites west of the OTA (Hell Hole Peregrine, Swan Dam Draw, Swan Dam Road South Side) where we used a truck (sitting inside or next to it) or a portable blind. We used blinds at Massacre Face and Powerline only once because the nests had failed; nest failure appeared to occur before the onset of our observations.

As in 1991-1993, we maximized the number of territories observed rather than the number of days each territory was observed. This year, we observed 11 nests during both the early brood-rearing (nestlings <21 days old) and late brood-rearing periods (nestlings 21 - 40 days old; Table 1). In total, we completed 58 full days of observation. As in previous years, our observation schedule was not randomized because of logistical constraints (territories close to each other were observed during the same week) and military training schedules (observation days were paired to watch on training and non-training days).

Ten observers, divided into 2 groups, conducted all behavioral observations. One group observed the OTA shadow territories, and the other group observed the territories west of the OTA. Differences between observers were minimized by training which included 1 day of indoor instruction and 1 day of observing prairie falcons at an aerie while recording behavioral data. Observers further sharpened their skills by watching falcon pairs and locating their scrapes. Late in the season, some OTA shadow observers watched aeries west of the OTA because of nest failures in the OTA shadow. Data collected included the parents' time budgets and prey handling activities, and weather conditions, asdescribed in Marzluff et al. (1991, 1992, 1993).

Analyses.--In previous years, we analyzed parental attendance and prey delivery rates (collected during 2 time periods: early and late brood-rearing) using repeated measures ANOVAs. The small sample of complete behavioral observations for a nest throughout the brood-rearing period in the OTA shadow precludes using this type of analysis for all 4 years' data. Therefore, we analyzed male and female behavior separately within the 2 time periods using MANOVAs with 2 factors, OTA (nesting areas in the OTA shadow versus west of the OTA) and year (1991, 1992, 1993, 1994), and 2 covariates (brood size and hatch date). If the main effect of year and the interactions between year and OTA were not significant, then we interpreted the effects of OTA in the analysis of pooled data (1991-1994). Multiple observations of behavior within the early and late brood-rearing periods were averaged to increase the normality of the response variables. We transformed percentages (arcsine of the square root) before analysis. We used correlation analysis to test for the effects of brood size and hatch date on our measures of parental attendance and prey handling rates.

Sample sizes for paired observations of parental behavior on military training and non-training days were small for each year of the study. Therefore, we pooled all data (1991-1994) to test for military training effects. We sampled behavior of falcons nesting within the OTA shadow on 21 pairs of days and those nesting west of the OTA on 17 pairs of days (within 1 - 5 days of each other); 1 day in each pair was a day when training occurred on the OTA

Table 1. Prairie falcon territories, in the OTA shadow and west of the OTA, where prey delivery observations were conducted in 1994. The stage of the breeding cycle when observations were made is marked (X) for each territory.

	BREEDING CYCLE		
Territory	Incubation	Early Brood Rearing	Late Brood Rearing
OTA SHADOW NESTS			
Black Butte	X	X	X
Colt Downstream		X	X
CSJ		X	X
Massacre Face[a]			
No Bird Rock	X		
Powerline[a]			
Sand Rock		X	X
WEST OF OTA NESTS			
Corral		X	X
Corral Downstream		X	X
Dedication Site Upstream	X	X	
Halverson Trail	X	X	X
Hell Hole Peregrine	X	X	X
PF I	X	X	X
Swan Dam Draw		X	X
Swan Dam Road South Side		X	X

[a]Nest failure occurred before first observation at this site.

ranges, and the other day was a day when training did not occur. We compared average behavior on training versus non-training days using a repeated measures ANOVA with nestling age as a covariate. The model had 1 repeated measures factor (training versus non-training). To test for any difference in weather conditions between training days and non-training days, we used a MANOVA with 7 weather variables and 1 factor with 2 levels (training and non-training). Weather data were collected at Swan Falls Dam and from the National Weather Service (Boise airport).

We used log-linear models to test for the 3-way interaction among 3 prey-type categories (Townsend's ground squirrels [*Spermophilus townsendii*], mammals, and birds and reptiles) delivered fresh to the territory, year (1992, 1993, 1994), and nest location (OTA shadow and west of the OTA). We excluded the unidentified prey category from this analysis because we were interested only in comparing differences in known prey types. Prior to excluding this category we checked to ensure that the proportion of unidentifiable prey items did not differ among years ($F_{(1,42)} = 0.28$, $P = 0.76$).

Behavior and Abundance of Raptors on the Orchard Training Area

Field Protocol.--We monitored the abundance and behavior of raptors on 11 firing ranges, 3 bivouac/maintenance areas, and 1 lane training area for a total of 587 hr (71 observer days) during April, May, June, July, and August 1994. Ranges were inside the circular cinder Range Road and extended toward an artillery impact area. Bivouac/maintenance areas were both inside and outside

Range Road. Our study areas on ranges were described in Marzluff et al. (1991) and included 5 tank training ranges (ranges 1, 5, 10, 11, 26), 2 small arms firing range (ranges 14, 15), 1 artillery range (30), and 3 ranges utilized for a variety of firing activities (ranges 3, 6, 22). In 1994, we continued to examine the influence of military training exercises outside Range Road on raptor abundance and behavior. We surveyed tank lane training areas using scans similar to those at bivouac/maintenance areas. Scanning procedures at firing ranges, behaviors recorded, and military activity categories were described in Marzluff et al. (1991), and scanning procedures for bivouac/maintenance study areas were described in Marzluff et al. (1992). The standard observation period at firing ranges and at bivouac/maintenance sites began at 0700 hr and continued until 1500 hr (MST). We sampled 1 range 6 times from 0700 hr until dusk (approximately 2040 hr).

We sampled each range and bivouac/maintenance area on days when the activity was taking place (hereafter referred to as *active*, *training* or *firing* days) and again on days when no activity occurred (*inactive*, *non-training* or *non-firing* days). Each daily survey of raptor and military activity was conducted by a single observer. In 1994, 6 individuals acted as observers. Three of the observers surveyed ranges during the 1991, 1992, 1993, and 1994 study seasons; 1 other observer surveyed ranges during the 1992, 1993, and 1994 seasons. Each individual surveyed most ranges at least once on a training day and once on a non-training day.

Analyses.--We categorized military use of ranges as described in Marzluff et al. (1993). We obtained range-use data for 1994 from the Idaho National Guard and compared the daily counts of personnel and vehicles to the average number of raptors observed per hour on the ranges to determine if there was a correlation between numbers of raptors using the ranges and the level of activity on the OTA. We tested the hypothesis that morning and afternoon observations were unbiased assessments of raptor abundance and military activity by comparing mean numbers of raptors observed in the evening at 1 range (10) to those observed during our typical observation period. Marzluff et al. (1991) described the remaining analyses performed. In all analyses of multiple years of data, we investigated whether raptor abundance or behavior differed between years.

Golden Eagles

Trapping and Observations.--We trapped at 2 territories in 1994 where previously instrumented eagles had nonfunctioning transmitters (PP&L 119 and Cabin). We again trapped non-canyon nesting golden eagles wintering in the OTA (Appendix B) and instrumented them with both backpack satellite transmitters and tail-mounted conventional transmitters. We did not band nestlings in 1994.

We trapped as described in Marzluff et al. (1993) with the addition of using a radio-controlled bow net to increase the selectivity of trapping. However, incidental captures still occurred when the eagle in the trap could not be positively identified, and non-target eagles were captured to ensure that a target bird was not missed.

We observed behaviors (Marzluff et al. 1992) and monitored the breeding status of radio-marked golden eagles at 7 territories in 1994. This represented a decrease of 2 territories from 1993 due to the death of the radio-marked female at the Pole 369 territory, and the disappearance of the radio-marked male at the Grand View Sand Cliff territory. Marzluff et al. (1993) described the selection of control territories.

Analyses.--We used a 2-factor (presence of radiotag and year) log-linear model to test for the effect of radio-tagging on the success of eagles. To test for differences between the number of fledglings produced by control and radio-tagged pairs, we used a 1-factor (presence of radiotag) ANOVA with 1 repeated measure (year). We used a repeated-measure ANOVA because the same eagles were monitored each year. We used a 2-factor (year and presence of radiotag) ANOVA to test for differences between the number of fledglings produced by successful control versus successful radio-tagged eagles, because sample sizes were too small to use a repeated measures ANOVA. We recognize that treating the data as independent may increase the likelihood of a Type I error.

Analysis of travel distances differed from previous years. In 1994, we defined season as either breeding or non-breeding. We defined breeding as the time from when eagles were first observed working on the nest or incubating, until nestlings fledged or the breeding attempt failed; non-breeding included all times not within the breeding period. Seasons were of different duration for each territory based on individual circumstances. We analyzed all 4 years' data using a 2-factor repeated-measures ANOVA, with travel distances by year and season as the repeated measures. We only had 5 adequately sampled territories to run this analysis. Mean seasonal travel distances did not vary among years; therefore, we pooled data across years and used data from 8 territories to examine seasonal and territorial differences in travel distance using a 2-factor (season and territory) ANOVA.

RESULTS

Activity of Prairie Falcons Inferred from Radio Telemetry

Influence of Telemetry Packages.--Radio-tagged prairie falcons did not have significantly lower nesting success than unmarked falcons ($G^2_{(3)} = 3.8$, $P = 0.28$), but the likelihood of nesting successfully varied among years for all falcons ($G^2_{(3)} = 46.18$, $P < 0.001$). Similarly, we found no significant difference in success rates between radio-tagged males and females ($G^2_{(3)} = 2.45$, $P = 0.49$), and the combined sample of males and females exhibited a variable success rate among years ($G^2_{(3)} = 30.21$, $P < 0.001$).

Radio-tagged falcons fledged the same number of young as non-radioed falcons ($F_{(1,136)} = 0.05$, $P = 0.83$), and fledgling numbers between treatment and control groups did not differ among years ($F_{(3,136)} = 0.51$, $P = 0.68$). In fact, the number of fledglings produced by all successful pairs appeared to be independent of any yearly variation ($F_{(3,136)} = 0.93$, $P = 0.43$).

Productivity did not depend upon the sex of the falcon radio-tagged ($F_{(1,48)} = 1.14$, $P = 0.29$), and there were no differences in the number of fledglings produced among years and between radio-tagged sexes ($F_{(3,48)} = 0.69$, $P = 0.56$). The number of fledglings produced by radio-tagged falcons also was independent of yearly variation ($F_{(3,48)} = 0.59$, $P = 0.62$).

Radio-tagged male falcons did not differ from control males in any of our measures of behavior. Radio-tagged males attended the territory ($F_{(3,31)} = 0.60$, $P = 0.62$) and the nest ($F_{(3,30)} = 0.82$, $P = 0.49$) and provisioned nestlings ($F_{(3,21)} = 2.31$, $P = 0.12$) at rates similar to control males. Similarly, radio-tagged females did not spend less time either in the territory ($F_{(3,30)} = 1.23$, $P = 0.32$) or at the nest ($F_{(3,31)} = 0.061$, $P = 0.98$) than control females. Delivery rates of fresh prey items to the nest tended to be variable among years and between radio-tagged and control females ($F_{(3,21)} = 3.173$, $P = 0.063$). Rates tended to be higher for radio-tagged females, except in 1993, when prey deliveries tended to be higher for control females. Radio-tagged females also cached prey at rates similar to control females ($F_{(3,21)} = 0.10$, $P = 0.91$).

Radio-tagged and control falcons raised fledglings of similar weights (male fledglings: $F_{(1,102)} = 1.75$, $P = 0.19$; female fledglings $F_{(1,114)} = 0.02$, $P = 0.89$, respectively). There were no differences in fledgling weights between radio-tagged and control falcons of either sex among years (males: $F_{(3,102)} = 0.77$, $P = 0.51$; females: $F_{(3,114)} = 0.36$, $P = 0.78$), yet female fledgling weights for all broods did vary among years ($F_{(3,114)} = 2.89$, $P = 0.04$). We did not detect any yearly variation in male fledgling weights for all broods ($F_{(3,102)} = 1.17$, $P = 0.32$).

The sex of the radio-tagged falcon did not affect the weights of male ($F_{(1,38)} = 0.94$, $P = 0.34$) or female ($F_{(1,42)} = 0.47$, $P = 0.50$) fledglings, and we found no differences in fledgling weights between male and female radio-tagged falcons among years (males: $F_{(3,38)} = 1.52$, $P = 0.23$; females: $F_{(3,42)} = 1.25$, $P = 0.30$). We did not detect any yearly variation in the smaller sample of female fledgling weights ($F_{(3,42)} = 0.72$, $P = 0.55$) or male fledgling weights ($F_{(3,38)} = 0.59$, $P = 0.63$).

Weather Effects on Falcon Activity.--Temperature influenced the movement of (and/or our ability to detect) radio-tagged falcons. A multiple regression model with wind speed, temperature, date, and time of day as independent factors, and number of

contacts or fixes as the dependent variable showed temperature to be the only significant factor (Fig. 1; Fixes: significance in multiple regression of Temp- $P < 0.001$, Temp^2- $P < 0.001$, Date- $P = 0.171$, Hour- $P = 0.89$, Wind- $P = 0.69$, Wind^2- $P = 0.99$; Overall model: $R^2 = 0.014$, n=1309, $P = 0.006$; Contacts: significance in multiple regression of Temp- $P < 0.001$, Temp^2- $P < 0.001$, Date- $P = 0.86$, Hour- $P = 0.77$, Wind- $P = 0.77$, Wind^2- $P = 0.42$; Overall model: $R^2 = 0.018$, n =1374, $P < 0.001$). For all years combined, temperature had the largest effect on falcon movements, with either high or low extremes reducing falcon movements.

Use of beacons.--Beacon testing produced data on 150 triangulations. Accuracy of the Maximum Likelihood Estimator (MLE), the Least Squares Estimator, and the Andrews estimator (Lenth 1981) were statistically indistinguishable, but the Andrews estimator produced the lowest linear errors (Linear error: $\bar{x}_{Andrews}$ = 1573 m, SE = 240, n = 126; $\bar{x}_{MLE}$ = 1611 m, SE = 237, n = 129; $\bar{x}_{LSE}$ = 1977 m, SE = 221, n = 149). We used the point estimate of a transmitter's location determined by the Andrews method because it was slightly more accurate than the MLE. Data from direct observations (presented below) also indicated that the Andrews estimator was slightly more accurate.

The error ellipse associated with the Andrews estimate was not used. Instead, we used a regression model that related properties of the triangulation to the linear error of the estimate. The sites contributing to a triangulation form the vertices of a polygon; the closer an estimate is to the geometric center of this polygon, the more accurate the estimate tends to be. This distance was the single most significant predictor of linear error (Estimated Linear error = -1782.49 + [0.712 × Distance from geometric center of polygon]; R^2 = 0.66, $F_{(1,128)}$ = 244.27, $P < 0.001$). We used the error estimated by regression as the radius of an error circle centered at the Andrews point estimate of the signal's location. Coverage of these modified circles was 80% (n = 130); that is, 80% of the fixes were covered by the resulting circles. In contrast, only 65% (n = 130) of error ellipses covered the true location. Coverage of ellipses varied by ellipse size, with smaller ellipses producing worse coverage than large ellipses. In contrast, coverage with the regression model was consistent at all levels. Applying the regression model to the direct observation data set produced coverage of 100% as compared to 70% coverage produced by error ellipses.

Direct observations of falcons.--Direct observations of falcons proved to be a valuable check of radio tracking accuracy, and provided an independent data set to use when testing models based on beacons. We obtained 30 direct observations of prairie falcons in 1993 and 29 in 1994 for a total of 59 direct observations upon which the radio tracking crew was simultaneously able to obtain a triangulation. Testing linear error in an ANOVA against the estimator, accuracy of location, and year showed that linear errors associated with visually "estimated" locations were greater than linear errors for "known" locations ($\bar{x}_{estimated}$ = 2281 m, n = 87, SE = 400 m, $\bar{x}_{actual}$ = 997 m, n = 90, SE = 388 m, $F_{(1,165)} = 5.28$, $P = 0.02$). Linear errors associated with visual observations from 1993 were almost 3 times those from 1994 ($\bar{x}_{1993}$ = 2404 m, n = 90, SE = 388 m, $\bar{x}_{1994}$ = 874 m, n = 87, SE = 400 m, $F_{(1,165)} = 7.5$, $P = 0.01$). We used estimates only from known locations when testing models based on beacons. The Andrews and MLE estimators were more accurate than LSE estimator when direct observation data were examined, although this difference was not significant (Linear error: $\bar{x}_{Andrews}$ = 1566 m, SE = 483, n = 59; $\bar{x}_{MLE}$ = 1591 m, SE = 483, n = 59; $\bar{x}_{LSE}$ = 1760 m, SE = 483, n = 59, $F_{(2, 165)} = 0.047$, $P = 0.95$). We observed only 1 kill and 1 case of a recent kill. We recorded habitat only once for each falcon, unless it moved significantly while being observed; therefore, the number of habitats recorded is lower than the number of triangulations on birds under direct observation. Observations were spread through a variety of habitats, with 2 sites in highly disturbed grasslands, 3 in cheatgrass (*Bromus tectorum*)-dominant, 3 in low-density Russian thistle (*Salsola iberica*)/native grass, 3 in medium-density tumbleweed/native grass, 2 in cheatgrass/native grass, and 2 in sagebrush (*Artemisia tridentata*)-dominant areas. The documented kill occurred in a highly disturbed grassland area. NBS personnel observed 2 successive kills of small rodents directly below a falcon's aerie on a sandy talus slope (Emily Teachout, RRTAC, pers. commun.).

Home range analyses.--From 1991 to 1994 we collected data on 58 falcons that successfully reared fledglings, 19 that failed to successfully rear nestlings to fledging age, and 18 that never bred. We obtained a total of 7,213 acceptable fixes (n_{1991} = 1911, n_{1992} = 1413, n_{1993} = 1969, n_{1994} = 1920). Maps of 95% harmonic mean home ranges of falcons adequately sampled in 1994 are shown in Figs. 2 - 13. Maps from previous years are not comparable to 1994 maps due to the change in fix selection technique. We revised data for previous years and present several measures of home range size, travel distance, and home range shape in Tables 2 - 9.

Ranging habits of falcons varied more among years than with respect to nesting status. Outer ranges varied by year, with 1991 and 1992 falcons showing smaller home ranges than 1993 and 1994 falcons (Fig. 14; MANOVA testing minimum convex and 95% harmonic mean simultaneously: year effect-multivariate $F_{(6,164)}$ = 2.83, P = 0.01). Successful birds tended to have smaller outer ranges than failed nesters, who had smaller ranges than non-nesters, but differences were marginally significant (Fig. 14; MANOVA testing minimum convex and 95% harmonic mean simultaneously: success effect: *Multivariate* $F_{(4,164)}$ = 2.83, P = 0.09). When we examined inner ranges, year remained a significant factor, with ranges increasing from 1991 to 1994 (Fig. 14; MANOVA 50% convex polygon and 50% harmonic mean range simultaneously: year effect: *Multivariate* $F_{(6,164)}$ = 2.11, P = 0.05). Inner home ranges did not significantly change with nesting status (Fig. 14; MANOVA 50% convex polygon and 50% harmonic mean range simultaneously: success effect: *Multivariate* $F_{(1,164)}$ = 0.98, P = 0.43). Travel distances from the aerie did not vary with falcon nesting success (Fig. 15; MANOVA testing mean and maximum distances from the nest simultaneously: success effect: *Multivariate* $F_{(2,68)}$ = 0.98, P = 0.38), nor did they vary by year (Fig. 15; MANOVA mean and maximum distances from the nest simultaneously: year effect: *Multivariate* $F_{(1,136)}$ = 1.64, P = 0.14). This lack of a year effect was perplexing because it occurred in every other analysis. The minor year effect appears to be due to a marginally significant interaction between year and breeding status (MANOVA on mean and maximum distances from the nest by year and success: $F_{(6,136)}$ = 1.81, P = 0.10). Examining this interaction more critically we found that travel distances for successful birds varied significantly among years (MANOVA testing mean and maximum distances from the nest by year, for successful birds only: $F_{(6,106)}$ = 3.97, P = 0.001), but travel distances for failed breeders did not (MANOVA testing mean and maximum distance from the nest by year, for failed breeders only: year effect: $F_{(6,26)}$ = 1.26, P = 0.32). The number of failed and non-nesting falcons was much higher in 1993 than in other years (Fig. 15; $X^2_{(6)}$ = 30.24, P < 0.001). Therefore, the analysis combining successful and failed breeders may be distorted by the unusually large number of failed breeders in 1993.

Falcons nesting in the OTA shadow ranged farther from their nests than did falcons nesting west of the OTA (Fig. 16; MANOVA comparing mean and maximum distances from the nest simultaneously: location effect: *Multivariate* $F_{(2,60)}$ = 12.6, P < 0.001). Differences among years again were evident, with birds from 1992 travelling shorter distances, regardless of whether they nested in the shadow or west of the OTA (Fig. 16; MANOVA comparing mean and maximum distances from the nest simultaneously: year effect: *Multivariate* $F_{(6,120)}$ = 5.79, P < 0.001). Males tended to travel farther from the nest, but had lower mean travel distances (Fig. 16; MANOVA comparing mean and maximum distances from the nest simultaneously: sex effect: *Multivariate* $F_{(2,60)}$ = 3.08, P = 0.06). Home ranges based on minimum convex polygons and 95% harmonic mean range varied only by year, with the smallest ranges occurring in 1992 and the largest in 1994 (Fig. 14; MANOVA comparing minimum convex polygons and 95% harmonic mean range simultaneously: year effect: *Multivariate* $F_{(6,156)}$ = 5.81, P < 0.001). These outer home ranges did not vary by nest location or by sex of the falcon. When we examined the inner 50% convex polygons and 50% harmonic mean ranges, home ranges varied with no consistent differences among sexes, nesting location, or year. (Fig. 17; MANOVA comparing 50% convex polygons and 50% harmonic mean ranges simultaneously:

Table 2. Home range characteristics of paired prairie falcons in the SRBOPA determined from radiotelemetry in 1991. Distances are recorded in meters and home ranges are recorded in hectares. Table headings are abbreviated as follows: Hc-harmonic center, Ac-arithmetic activity center.

Nesting Area[a]	Sex	OT[b]	N	Mean distance from:				Max distance from:			Harmonic Mean Home Range				Convex Polygon Home Range			
				Nest	Hc	Ac	Hc-Nest	Nest	Hc	Ac	Max	95%	90%	50%	Max	90%	70%	50%
Beech	M	W	1	5,36	1,85	4,404	2,949	27,0	27,290	25,700	132,4	23,5	18,451	3,795	43,850	14,4	5,430	2,817
WhFF	F	S	4	8,27	2,33	9,397	927	16,4	15,890	12,740	998	998	998	34	5,984	5,98	266	<1
BrcsD	M	S	1	7,09	1,62	5,238	2,660	32,9	31,580	27,570	107,3	21,6	14,549	3,493	33,900	11,5	5,811	2,165
BBH	F	W	3	7,35	2,22	4,654	5,584	23,5	21,890	21,410	57,14	20,1	15,449	3,157	21,810	8,92	3,681	1,843
MGUp	F	W	5	5,91	2,25	4,236	2,150	12,1	11,070	8,103	15,64	12,3	12,270	2,445	12,790	1,09	7,808	4,860
OgRkD	F	W	4		2,04	4,884			27,260	22,150	78,19	27,4	9,788	4,117	30,530	6,44	5,016	3,630
PrRI	F	W	4	3,77	1,10	2,830	2,598	9,57	7,135	7,484	9,117	6,58	5,630	841	6,339	4,50	1,919	625
Bitch	M	W	1	6,60	1,22	4,777	5,414	26,5	21,500	21,120	107,6	33,9	18,762	5,076	44,610	14,4	6,754	3,935
BBPI	F	W	2		2,46	6,089			23,250	22,580	25,28	24,6	21,113	2,020	22,910	10,7	4,179	1,759
CSJ	M	S	7	10,2	2,54	5,975	13,761	29,5	21,360	21,320	80,15	29,1	18,084	4,724	25,790	16,7	10,570	6,219
PlMlr	M	S	9	6,64	2,11	4,808	5,375	20,9	19,930	18,050	68,21	32,9	22,503	3,824	33,860	12,4	5,842	3,579
CGG	M	W	1	5,44	2,00	4,294	453	27,2	27,210	26,070	99,45	18,2	13,046	4,015	31,830	10,9	7,818	3,821
FwnHb	M	S	1	9,34	2,81	4,521	7,705	15,6	10,000	8,264	7,515	6,30	4,673	1,199	11,250	5,88	3,273	2,012
SwlDr	F	S	5	8,25	3,16	5,975	1,855	18,1	17,220	13,320	41,62	27,9	22,056	4,848	32,430	20,1	14,350	5,343
FvBs	F	S	6	7,22	2,68	5,300	1,909	19,5	18,000	17,940	52,19	19,8	13,983	5,110	22,940	13,4	8,474	4,795
PChm	F	W	6	4,52	956	3,387	4,282	21,3	20,050	20,250	57,01	13,8	6,729	1,952	18,150	6,41	3,056	1,731
TickIII	F	S	1		1,42	4,432			11,250	8,907	6,055	5,80	4,752	1,263		6,00	2,252	476
WhSW	M	S	8	10,5	2,86	7,487	122	23,7	23,630	19,820	90,49	9,99	8,914	8,794	45,390	29,7	19,740	9,612
BPtUp	F	S	9	7,28	1,83	4,897	7,889	15,6	14,440	13,740	41,78	21,2	15,087	4,222	20,610	15,4	7,964	4,339
HHGS	M	W	1	3,05	115	2,408	7,369	20,2	17,160	19,250	72,90	8,53	5,878	1,698	16,950	5,14	2,441	2,116
PrUp	M	W	1	5,97	1,63	4,835	4,343	20,7	19,170	18,870	73,87	25,5	20,318	5,040	30,680	15,5	9,286	3,833
TmBtW	F	S	5	11,8	3,23	8,085	15,358	24,8	20,540	15,170	11,44	40,3	34,692	6,457	44,760	37,5	27,610	13,180
WhNE	M	S	8	9,06	1,88	6,725	749	22,9	22,450	15,940	67,36	27,3	17,972	3,853	34,030	19,6	13,540	7,383
Fang	F	W	5		1,42	3,350			19,650	16,870	52,67	18,8	14,456	1,098	17,200	6,16	1,612	834
BBGE	F	W	3	5,70	1,65	3,520	4,256	13,2	11,030	11,650	18,84	10,8	8,595	1,913	10,430	6,32	2,545	1,145
Cabin	F	S	8	12,3	3,37	8,579	28,142	32,1	30,600	51,140	96,79	48,4	41,902	8,249	51,480	44,1	37,280	27,630

[a] Nesting area names are as follows: Beech=Beehcam, WhFF=Wildhorse Face Fenceline, BrcsD=Beercase Downstream, BBH=Balls Basin Hamer, MGUp=Mother Giant Upstream, OgRkD=Ogden Rock Downstream, PrRi=Priest Rapids I, Bitch=Bitch, BBPI=Balls Basin Powerline, CSJ=CSJ, PlMr=Powerline Mirror, CGG=Cattleguard Gate, FwnHb=Fawn Humpback, SwlDr=Swan I Draw, FvBs=Fever Basin, PChm=Peregrine Chimney, TickIII=Tick III, WhSW=Wildhorse SW, BPtUp=Balls Point Upstream, HHGS=Hell Hole Gaging Station, PrUp=Priest Upper, TmBtW=Tom Butte West, WhNE=Wildhorse NE, Fang=Fang, BBGE=Balls Basin GE, Cabin=Cabin.

[b] OTA abbreviations are as follows: S=nesting area within the OTA shadow, W=nesting area west of the OTA shadow, N=no known nesting area.

Table 3. Home range characteristics of paired prairie falcons determined from radiotelemetry in 1991. Distances are recorded in meters and home ranges are recorded in hectares. Table headings are abbreviated as follows: Hr-sum of the reciprocal distance (d^{-1}) to each fix, divided by the number (n) of distances and then re-inverted (i.e. $n/\Sigma d^{-1}$), D-dispersion, Sk-skewness, K-kurtosis, Sp-spread.

				Home Range Shape								
					Harmonic Mean					No. Locations inside:		
Nesting Area[a]	Sex	OTA[b]	N	Maximum Polygon width	Hr	D	Sk	K	Sp	OTA (%)	Range Rd	(%)
Beech	M	W	172	33,720	1,867	2.19	2.17	3.90	3,320	17 (10)	2	(1)
WhFF	F	S	4	19,440	3,109	1.36	1.54	2.29	5,219	1 (33)	0	(0)
BrcsD	M	S	134	33,350	1,639	3.94	10.13	8.18	3,402	37 (28)	27	(20)
BBH	F	W	34	30,790	2,290	1.14	0.24	1.91	3,830	2 (6)	3	(9)
MGUp	F	W	53	14,770	2,295	2.26	3.78	3.76	3,814	4 (8)	0	(0)
OgRkD	F	W	49		2,092	2.52	6.63	4.45	3,694	1 (2)	0	(0)
PrRI	F	W	43	14,110	1,131	1.55	0.47	2.95	2,148	2 (5)	0	(0)
Bitch	M	W	169	29,920	1,227	6.60	7.79	19.84	3,686	22 (13)	2	(1)
BBPl	F	W	24	32,130	2,572	1.31	0.50	2.30	4,502	5 (21)	0	(0)
CSJ	M	S	73	31,200	2,576	3.22	6.51	5.74	4,585	19 (26)	26	(36)
PlMIr	M	S	93	25,220	2,142	3.08	2.73	5.30	3,681	41 (45)	16	(17)
CGG	M	W	109	31,710	2,026	3.28	7.28	5.54	3,423	5 (5)	0	(0)
FwnHb	M	S	17	15,690	2,986	1.11	0.88	1.62	4,354	5 (31)	5	(31)
SwlDr	F	S	56	24,630	3,223	1.72	3.08	2.72	5,071	10 (18)	1	(2)
FvBs	F	S	62	25,400	2,725	1.56	2.58	2.59	4,524	12 (20)	0	(0)
PChm	F	W	64	24,930	971	2.96	2.58	7.40	2,427	1 (2)	0	(0)
TickIII	F	S	16	14,890	1,515	1.35	2.29	2.81	3,155	2 (13)	0	(0)
WhSW	M	S	81	32,080	2,905	2.87	8.88	5.8	5,874	28 (35)	10	(13)
BPtUp	F	S	99	22,240	1,855	3.27	3.42	6.83	3,877	26 (27)	0	(0)
HHGS	M	W	119	23,090	116	10.62	484.93	135.77	1,487	2 (2)	0	(0)
PrUp	M	W	141	25,320	1,650	4.73	1.22	11.13	3,879	18 (13)	1	(1)
TmBtW	F	S	55	29,820	3,294	2.48	4.33	5.00	6,631	19 (35)	1	(2)
WhNE	M	S	88	26,710	1,904	2.04	8.26	3.94	3,674	25 (29)	2	(2)
Fang	F	W	59	23,360	1,449	1.49	2.96	2.38	2,313	5 (8)	0	(0)
BBGE	F	W	32	19,900	1,705	1.49	.62	2.72	3,111	4 (13)	0	(0)
Cabin	F	S	85	34,620	3,415	7.11	35.23	12.68	6,093	25 (30)	35	(42)

[a] Nesting area names are as follows: Beech=Beecham, WhFF=Wildhorse Face Fenceline, BrcsD=Beercase Downstream, BBH=Balls Basin Hamer, MGUp=Mother Giant Upstream, OgRkD=Ogden Rock Downstream, PrRi=Priest Rapids I, Bitch=Bitch, BBPl=Balls Basin Powerline, CSJ=CSJ, PlMr=Powerline Mirror, CGG=Cattleguard Gate, FwnHb=Fawn Humpback, SwlDr=Swan I Draw, FvBs=Fever Basin, PChm=Peregrine Chimney, TickIII=Tick III, WhSW=Wildhorse SW, BPtUp=Balls Point Upstream, HHGS=Hell Hole Gaging Station, PrUp=Priest Upper, TmBtW=Tom Butte West, WhNE=Wildhorse NE, Fang=Fang, BBGE=Balls Basin GE, Cabin=Cabin.

[b] OTA abbreviations are as follows: S=nesting area within the OTA shadow, W=nesting area west of the OTA shadow.

Table 4. Home range characteristics of paired prairie falcons in the SRBOPNCA determined from radiotelemetry in 1992. Distances are recorded in meters and home ranges are recorded in hectares. Table headings are abbreviated as follows: Hc-harmonic center, Ac-arithmetic activity center.

Nesting Area[a]	Sex	OTA[b]	N	Mean distance from:				Max distance from:			Harmonic Mean Home Range				Convex Polygon Home Range			
				Nest	Hc	Ac	Hc-Nest	Nest	Hc	Ac	Max	95%	90%	50%	Max	90%	70%	50%
PCliff	M	W	93	3,010	884	2,978	1,155	13,060	14,060	11,780	28,228	11,294	9,146	1,142	12,260	5,093	2,135	1,329
WPt	M	W	72	5,407	837	4,651	899	19,030	19,040	15,930	45,272	17,578	16405	2,162	18,600	12,080	3,980	1,557
Tick3	M	S	55	3,796	742	3,660	1,479	12,850	11,430	11,650	19,978	16,945	10,459	1,770	15,010	8,583	3,035	1,736
FngDS	M	W	81	5,899	732	2,563	1,807	18,700	17,550	16,960	62,003	13,384	9,479	865	25,750	4,148	985	432
FFCE	M	W	55	3,591	1,285	2,888	2,790	13,210	11,730	10,710	20,806	8,870	5,946	1,063	10,130	4,411	1,559	960
BBFer	M	S	71	6,457	1,259	5,798	2,018	24,340	22,740	19,570	69,950	45,629	39,898	4,204	34,240	16,310	6,038	2,806
TDDS	M	S	63	5,489	1,219	4,618	1,257	24,420	20,190	20,190	59,135	25,578	14,598	2,026	22,510	7,838	3,462	1,726
FFE	M	W	71	9,451	2,427	9,474		35,390	35,240	30,010	77,804	49,976	45,793	4,547	47,250	36,820	9,799	2,791
Nahas	M	S	78	7,034	2,792	5,703	1,302	18,400	17,940	14,480	43,339	24,536	20,783	7,243	26,350	19,160	13,230	8,412
CGUS	M	W	61	3,763	1,022	3,006	2,887	29,320	19,930	29,780	89,590	11,240	6,294	1,496	22,260	3,353	1,663	738
BcsDw	M	S	54	5,436	1,665	4,653	2,673	27,350	25,040	22,900	83,471	21,819	19,719	2,706	22,450	11,390	3,246	1,197
PrRp2	M	W	58	2,996	922	2,161	3,447	9,671	9,951	8,620	14,474	8,488	4,717	563	8,004	2,930	1,009	336
OgR	F	W	46	3,881	1,599	3,174	2,091	11,510	9,587	8,888	14,358	9,192	6,954	1,598	9,441	5,959	2,024	1,253
Sw1DW	F	S	59	6,282	1,559	4,325	3,341	16,050	22,900	13,230	34,512	21,051	11,659	3,795	19,190	11,320	4,597	3,062
TdplLk	M	S	42	4,510	878	4,888	518	21,300	21,420	18,610	49,921	24,811	19,298	2,067	19,790	12,420	2,117	737
Ptrgl	F	W	30	6,651	828	7,400	3,004	26,910	25,840	22,970	27,767	22,741	21,003	1,128	21,240	12,230	2,224	450
S1DMD	M	S	59	6,369	2,756	5,504	3,475	17,870	19,900	13,880	40,292	27,637	16,371	5,572	24,620	14,510	9,383	5,901
TomDw	F	S	31	2,797	956	2,487	642	11,730	10,750	10,750	12,893	5,801	4,202	799	6,478	2,165	1,207	489
MGUp	F	W	42	2,645	990	2,625	1,491	10,200	9,119	9,390	13,733	6,788	5,429	1,123	6,881	4,762	1,764	683
HHGt	M	W	47	8,197	2,376	5,618	7,151	19,330	18,280	17,020	52,753	26,502	17,756	5,091	27,660	11,780	9,274	4,596
Sld2	M	S	30	5,298	1,875	3,578	4,881	15,950	12,150	12,750	20,408	11,941	11,049	1,364	14,950	6,138	2,331	862
BPtUS	M	S	31	7,374	2,776	5,832	2,647	21,900	18,030	18,030	37,533	16,708	11,675	3,795	16,850	10,540	5,446	2,780
Unkn[c]	F	W	49		3,084	6,702			19,130	13,800	41,972	36,364	28,176	6,782	30,740	24,670	14,540	7,571
SlDw	F	W	39	4,402	1,337	3,566	124	15,360	15,330	12,250	21,886	12,839	8,485	1,360	12,090	6,781	2,308	999
BcsDS	F	S	13	9,658	2,841	8,104	10,546	20,840	12,690	12,750	5,524	5,139	5,139	1,376	8,155	7,687	6,017	2,771
HndDw	F	S	17	3,527	1,688	2,982	3,280	7,777	6,258	5,768	3,790	2,125	1,898	368	4,001	2,819	2,174	1,433
Sw1DM	F	S	23	6,108	1,852	3,790	3,210	15,770	14,410	13,750	16,486	7,105	6,561	1,701	11,780	6,033	2,109	1,251
HlvSp	F	W	24	5,854	2,302	5,204	738	14,320	13,510	12,210	20,629	17,552	121,989	3,516	19,590	11,100	6,151	1,784
MssFc	F	S	21	2,579	,990	6,552	0	7,129	6,537	6,537	3,359	2,650	2,606	472	3,776	2,836	754	269
DdcPt	F	W	6	4,809	2,161	4,740	0	7,722	7,722	7,415	783	783	676	414	1,400	1,162	776	109
OgGE	F	W	13	4,464	748	4,821	1,145	14,710	15,240	12,580	6,937	6,053	6,035	392	3,745	2,650	604	215

[a] Nesting area names are as follows: PCliff=Peregrine Cliff, WPt=West Point, Tick3=Tick III, FngDS=Fang Downstream, FFCE=Falcon Flats Cave East, BBFer=Black Butte Ferrug, TDDS=Thirst Draw Downstream, FFE=Falcon Flats Engine, Nahas=Nahas, CGUS=Cattleguard Upstream, BcsDw=Beercase Draw, PrRp2=Priest Rapids II, OgR=Ogden Rock, Sw1DW=Swan 1 Draw West, TdplLk=Tadpole Lake, Ptrgl=Petroglyphs, S1DMD=Swan 1 Draw Mouth Downstream, TomDw=Tom Draw, MGUp=Mother Giant Upstream, HHGt=Hell Hole Gate, SlDw=Slice Draw, BcsDS=Beercase Downstream, HlvSp=Halverson Spring, MssFc=Massacre Face, DdcPt=Dedication Point, OgGE=Ogden GE77.

[b] OTA abbreviations are as follows: S=nesting area within the OTA shadow, W=nesting area west of the OTA shadow.

[c] This individual was trapped in the Red Trail nest area but was not a member of the Red Trail nesting pair and never established a nesting territory.

Table 5. Home range characteristics of paired prairie falcons determined from radiotelemetry in 1992. Distances are recorded in meters and home ranges are recorded in hectares. Table headings are abbreviated as follows: Hr-sum of the reciprocal distance (d^{-1}) to each fix, divided by the number (n) of distances and then re-inverted (i.e. $n/\Sigma d^{-1}$), D-dispersion, Sk-skewness, K-kurtosis, Sp-spread.

				Home Range Shape								
					Harmonic Mean					No. Locations inside:		
Nesting Area[a]	Sex	OTA[b]	N	Maximum Polygon width	Hr	D	Sk	K	Sp	OTA(%)		Range Rd (%)
PCliff	M	W	93	19,600	893	5.32	14.88	12.81	2,150	6	(7)	0 (0)
WPt	M	W	72	20,880	849	3.61	17.46	11.21	2,633	1	(1)	0 (0)
Tick3	M	S	55	18,810	756	4.02	6.62	14.24	2,673	4	(7)	0 (0)
FngDS	M	W	81	23,730	741	2.69	2.61	5.50	1,514	4	(5)	1 (1)
FFCE	M	W	55	15,470	1,309	2.08	2.44	3.58	2,247	4	(7)	0 (0)
BBFer	M	S	71	30,130	1,277	2.86	7.15	8.03	3.588	8	(11	6 (9)
TDDS	M	S	63	2,572	1,239	2.79	7.99	6.66	2,959	17	(27)	7 (11)
FFE	M	W	71	45,520	2,461	1.45	3.17	2.78	4,716	15	(21)	2 (3)
Nahas	M	S	78	24,090	2,829	2.99	5.55	5.25	4,969	17	(22)	2 (3)
CGUS	M	W	61	34,310	1,039	2.25	2.04	4.56	2,097	0	(0)	0 (0)
BcsDw	M	S	54	29,240	1,696	2.49	3.19	4.45	3,088	15	(28)	6 (11)
PrRp2	M	W	58	12,770	938	2.45	3.74	4.03	1,544	2	(4)	0 (0)
OgR	F	W	46	13,400	1,635	1.79	0.77	3.10	1,635	0	(0)	0 (0)
Sw1DW	F	S	59	18,790	1,586	2.53	3.09	5.72	3,578	4	(7)	0 (0)
TdplLk	M	S	42	25,590	899	2.31	7.54	6.06	2,353	25	(61)	5 (12)
Ptrgl	F	W	30	31,560	856	2.69	9.38	7.69	2,444	2	(7)	0 (0)
S1DMD	M	S	59	22,460	2,803	3.03	7.46	5.3	4,902	8	(14)	0 (0)
TomDw	F	S	31	17,060	987	1.45	1.63	2.86	1,950	2	(7)	0 (0)
MGUp	F	W	42	12,840	1,014	2.48	1.78	5.02	2,053	1	(2)	0 (0)
HHGt	M	W	47	23,960	2,427	2.54	1.43	4.85	4,637	13	(28)	0 (0)
Sld2	M	S	30	18,170	1,940	1.01	0.35	1.58	3,016	1	(3)	1 (3)
BPtUS	M	S	31	26,140	2,869	1.42	1.5	2.42	4,878	9	(30)	0 (0)
Unkn[c]	F	W	49	24,700	3,148	1.87	3.62	3.38	5,704	9	(18)	0 (0)
SlDw	F	W	39	16,550	1,372	2.18	5.61	4.36	2,738	1	(3)	0 (0)
BcsDS	F	S	13	22,700	3,078	1.92	1.66	3.08	4,913	4	(33)	3 (25)
HndDw	F	S	17	10,190	1,793	1.70	1.36	2.68	2,832	4	(25)	0 (0)
Sw1DM	F	S	23	19,350	1,936	1.5	1.42	2.65	3,717	0	(0)	0 (0)
HlvSp	F	W	24	20,260	2,402	1.43	1.75	2.72	4,563	0	(0)	0 (0)
MssFc	F	S	21	11,820	1,040	1.26	0.94	2.32	1,919	0	(0)	0 (0)
DdcPt	F	W	6	13,080	2,594	1.40	1.13	2.12	3,922	0	(0)	0 (0)
OgGE	F	W	13	22,240	810	2.20	7.27	5.63	2,065	2	(17)	0 (0)

[a] Nesting area names are as follows: PCliff=Peregrine Cliff, WPt=West Point, Tick3=Tick III, FngDS=Fang Downstream, FFCE=Falcon Flats Cave East, BBFer=Black Butte Ferrug, TDDS=Thirst Draw Downstream, FFE=Falcon Flats Engine, Nahas=Nahas, CGUS=Cattleguard Upstream, BcsDw=Beercase Draw, PrRp2=Priest Rapids II, OgR=Ogden Rock, Sw1DW=Swan 1 Draw West, TdplLk=Tadpole Lake, Ptrgl=Petroglyphs, S1DMD=Swan 1 Draw Mouth Downstream, TomDw=Tom Draw, MGUp=Mother Giant Upstream, HHGt=Hell Hole Gate, SlDw=Slice Draw, BcsDS=Beercase Downstream, HlvSp=Halverson Spring, MssFc=Massacre Face, DdcPt=Dedication Point, OgGE=Ogden GE77.

[b] OTA abbreviations are as follows: S=nesting area within the OTA shadow, W=nesting area west of the OTA shadow.

[c] This individual was trapped in the Red Trail nest area but was not a member of the Red Trail nesting pair and never established a nesting territory.

Table 6. Home range characteristics of paired prairie falcons in the SRBOPNCA determined from radiotelemetry in 1993. Distances are recorded in meters and home ranges are recorded in hectares. Table headings are abbreviated as follows: Hc-harmonic center, Ac-arithmetic activity center.

Nesting					Mean distance from:				Max distance from:			Harmonic Mean Home Range				Convex Polygon Home Range			
Area[a]	Sex	OTA[b]	N	Nest	Hc	Ac	Hc-Nest	Nest	Hc	Ac	Max	95%	90%	50%	Max	90%	70%	50%
RolRT	F	S	57		2,861	6,298			21,460	17,820	62,856	29,272	22,982	8,600	37,120	19,810	13,420	6,225
OgRUS	M	W	84	6,902	2,512	5,038	4,497	27,510	30,480	29,430	114,615	26,237	13,296	3,938	35,580	10,910	6,141	4,499
CGG	F	W	70	6,581	2,289	5,770	463	19,370	18,960	20,210	70,327	24,493	21,046	6,229	28,520	16,100	10,020	5,867
Unk	M	N	77		74	11,020			20,940	19,760	75,540	54,666	49,164	9,366	59,400	51,150	41,260	22,030
BPtF	M	S	97		94	6,094			24,840	17,390	81,754	36,662	24,363	7,551	39,760	28,800	20,780	16,310
MGUS	M	W	125	9,007	2,595	9,585	147	21,750	21,750	16,560	73,990	30,976	25,201	6,442	37,710	31,240	23,280	11,610
RsUrS	F	S	14	8,338	2,360	4,638	10,565	13,080	10,570	7,313	2,172	1,939	1,939	705	6,962	6,477	3,313	1,078
Unk	M	N	15		6,650	13,670			36,320	26,120	42,549	38,870	30,147	6,405	46,780	42,410	15,790	4,131
CoDS	F	W	34	6,798	1,121	6,186	1,380	17,950	17,300	14,380	31,035	25,615	22,956	2,362	23,800	17,770	9,475	2,072
FFC	M	W	98	7,996	1,578	7,936	1,011	38,320	37,900	32,800	168,063	94,489	42,026	2,852	70,620	30,380	5,956	1,487
WhBNE	M	S	94		4,021	6,979			25,070	16,870	60,803	39,596	32,714	11,702	43,480	25,940	19,360	14,160
PrUp	M	W	143	6,726	135	5,754	648	20,510	19,880	16,180	73,564	39,670	33,065	4,191	47,200	29,050	12,650	6,269
HHP	F	W	37	4,681	35	4,314	3,226	15,930	12,760	12,600	18,573	15,140	12,953	1,217	12,920	10,660	2,213	1,071
ConFl	M	S	34		3,786	8,765			25,140	21,990	63,564	38,861	38,088	10,537	41,720	28,840	19,120	11,110
HndDw	F	S	15	10,190	3,842	8,175	1,090	22,920	21,980	15,440	14,410	12,219	11,133	3,071	20,320	16,530	5,353	2,525
WoDw	M	W	94	8,147	125	6,670	1,308	25,730	24,500	19,450	91,480	42,757	34,858	6,373	43,970	25,660	16,210	6,974
Csbd	F	S	60	11,070	3,108	5,745	5,946	24,980	20,620	16,710	64,383	29,693	18,562	6,462	38,550	15,690	11,040	5,866
Ptrgl	F	W	38		1,910	8,240			39,440	39,990	159,230	70,161	40,195	5,564	44,790	18,000	5,573	1,585
Unk	F	N	38		3,336	5,824			14,850	15,070	42,158	25,041	22,683	3,620	31,910	22,800	6,815	2,912
PrIV	M	W	69	7,887	1,726	6,414	737	20,440	19,730	15,510	51,346	34,590	17,640	4,026	29,400	22,300	10,460	4,692
ChCbS	M	E	5		793	12,470			30,870	24,670	3,844	3,844	1,399	529	4,693	4,693	175	13
GufRk	M	W	74	4,490	69	3,290	5,051	19,940	20,020	18,130	56,150	14,412	8,977	1,529	22,650	5,163	3,123	1,729
BBI	M	S	58	10,350	2,428	8,525	1,405	29,590	28,180	27,090	139,480	62,700	39,188	8,678	65,840	36,420	21,370	8,606
SkCME	M	S	61		2,084	5,521			15,360	13,020	29,633	17,714	15,826	4,362	21,620	17,280	9,180	6,001
TBtW	M	S	86	9,547	3,929	6,671	2,022	22,380	24,380	15,670	61,180	33,149	28,118	9,655	37,590	25,040	18,930	12,520
PrRpl	F	W	53	4,631	1,240	3,506	3,709	16,920	16,280	15,310	37,579	12,652	10,816	1,563	16,700	6,222	2,308	1,381
JaNW	M	S	116	7,405	158	5,790	11,108	24,120	18,160	19,270	74,086	32,299	18,469	3,989	26,820	19,470	16,760	8,505
RsDw	F	S	29		1,958	6,341			14,080	10,900	16,285	16,093	8,937	2,599	21,030	19,230	8,949	3,517
Unk	M	N	9		2,287	2,647			4,444	3,558	313	313	291	204	2,039	1,390	838	405
SKBl	M	S	66		3,278	6,699			16,460	15,060	48,761	36,172	25,631	8,655	36,750	30,860	17,700	7,392
JBBGE	M	S	45		2,165	6,418			17,430	11,820	29,642	15,877	12,227	3,311	19,110	13,020	10,510	8,399
FvrBU	F	S	47		3,559	6,741			20,390	14,180	44,100	34,583	29,321	7,961	34,400	20,670	13,800	7,133
OgRUS	F	W	37	4,892	1,492	4,875	437	19,510	19,900	17,730	39,380	27,085	16,220	1,588	20,100	8,266	2,010	807

[a] Nesting area names are as follows: RolRT=Rosie I Red-tail, OgRUS=Ogden Rock Upstream, CGG=Cattleguard Gate, BPtF=Bails Point Face, MGUS=Mother Giant Upstream, RsUrS=Rosie Upriver South, CoDS=Colt Downstream, FFC=Falcon Flats Cave, WhBNE=Wildhorse Butte NE, PrUp=Priest Upper, HHP=Hell Hole Peregrine, ConFl=Conservancy Flats ,HndDw= Henderson Draw, WoDw=Wolf Draw, Csbd=Carlsbad, Ptrgl=Petroglyphs, PrIV=Priest IV, GufRk=Guffey Rock, BBI=Black Butte I, Fang=Fang, SkCME=Sinker Creek Mouth East, TBtW=Tom Butte West, PrRpl=Priest Rapids I, JaNW=Jackass NW, RsDw=Rosie Draw, SKBl=Sinker Bluff, JBBGE=Jackass BBGE, FvrBU=Fever Basin Upstream, Unk=Unknown

[b] OTA abbreviations are as follows: S=nesting area within the OTA shadow, W=nesting area west of the OTA shadow, N=no known nesting area.

Table 7. Home range characteristics of paired prairie falcons determined from radiotelemetry in 1993. Distances are recorded in meters and home ranges are recorded in hectares. Table headings are abbreviated as follows: Hr-sum of the reciprocal distance (d^{-1}) to each fix, divided by the number (n) of distances and then re-inverted (i.e., $n/\Sigma d^{-1}$), D-dispersion, Sk-skewness, K-kurtosis, Sp-spread.

Nesting Area[a]	Sex	OTA[b]	N	Home Range Shape: Maximum Polygon width	Harmonic Mean: Hr	D	Sk	K	Sp	No. Locations inside: OTA(%)		Range Rd (%)	
RolRT	F	S	57							24	(42)	3	(5)
OgRUS	M	W	84	36,690	2,542	2.28	1.82	3.43	3,818	2	(2)	0	(0)
CGG	F	W	70	29,390	2,322	1.78	3.63	3.39	4,409	3	(4)	0	(0)
Unk	M	N	77	38,390	76	8.64	451.48	244.08	2,156	22	(29)	14	(18)
BPtF	M	S	97	32,580	96	9.68	801.75	250.48	5,480	35	(36)	4	(4)
MGUS	M	W	125	32,210	2,616	2.67	7.90	5.26	5,144	48	(39)	6	(5)
RsUrS	F	S	14	13,080	2,542	1.14	1.70	1.93	4,298	5	(38)	0	(0)
Unk	M	N	15	42,100	7,125	1.06	1.53	1.61	10,787	2	(13)	5	(33)
CoDS	F	W	34	21,740	1,155	4.04	17.91	13.48	3,856	2	(6)	0	(0)
FFC	M	W	98	46,770	1,595	1.83	6.35	3.90	3,401	18	(19)	8	(8)
WhBNE	M	S	94	29,630	4,064	2.47	4.99	3.59	5,906	51	(55)	6	(7)
PrUp	M	W	143	58,920	136	11.33	371.69	244.00	2,930	22	(15)	0	(0)
HHP	F	W	37	19,650	36	5.90	37.27	88.30	544	1	(3)	0	(0)
ConFl	M	S	34	36,980	3,900	2.67	3.18	5.20	7,596	12	(35)	4	(12)
HndDw	F	S	15	24,580	4,117	1.15	2.11	1.87	6,700	5	(36)	0	(0)
WoDw	M	W	94	29,730	126	9.17	3.51	3.45	2,723	28	(30)	2	(2)
Csbd	F	S	60	27,770	3,161	2.24	3.51	3.45	4,854	34	(58)	5	(8)
Ptrgl	F	W	38	53,770	1,962	1.70	3.89	3.75	4,322	1	(3)	1	(3)
Unk	F	N	38	23,750	3,426	0.97	0.55	1.48	5,229	9	(24)	0	(0)
PrlV	M	W	69	30,020	1,752	3.03	10.44	7.62	4,402	23	(34)	2	(3)
ChCbS	M	E	5	31,890	991	1.37	8.61	2.59	1,878	4	(80)	0	(0)
GufRk	M	W	74	22,570	70	8.07	281.32	1188.00	1,188	1	(1)	0	(0)
BBl	M	S	58	41,350	2,470	2.85	8.79	6.81	5,900	8	(14)	21	(37)
SkCME	M	S	61	22,000	2,119	3.69	4.26	7.38	4,236	27	(44)	2	(3)
TBtW	M	S	86	25,980	3,976	4.02	9.95	6.01	5,950	30	(35)	4	(5)
PrRpl	F	W	53	20,160	1,263	2.64	2.05	5.29	2,534	6	(12)	0	(0)
JaNW	M	S	116	30,250	159	10.42	349.30	168.32	2,575	50	(43)	10	(9)
RsDw	F	S	29	21,480	2,028	3.21	5.65	7.07	4,458	12	(41)	1	(3)
Unk	M	N	9	6,398	2,573	0.53	0.18	0.66	3,206	2	(22)	0	(0)
SKBl	M	S	66	25,620	3,323	2.34	2.20	4.33	6,136	32	(48)	9	(14)
JBBGE	M	S	45	20,720	2,215	3.12	10.53	6.19	4,396	7	(16)	21	(47)
FvrBU	F	S	47	26,700	3,637	1.96	3.98	3.14	5,824	9	(19)	2	(4)
OgRUS	F	W	37	23,830	1,533	1.57	3.56	2.93	2,857	4	(11)	0	(0)

[a] Nesting area names are as follows: RolRT=Rosie I Red-tail, OgRUS=Ogden Rock Upstream, CGG=Cattleguard Gate, BPtF=Balls Point Face, MGUS=Mother Giant Upstream, RsUrS=Rosie Upriver South, CoDS=Colt Downstream, FFC=Falcon Flats Cave, WhBNE=Wildhorse Butte NE, PrUp=Priest Upper, HHP=Hell Hole Peregrine, ConFl=Conservancy Flats, HndDw=Henderson Draw, WoDw=Wolf Draw, Csbd=Carlsbad, Ptrgl=Petroglyphs, PrlV=Priest IV, GufRk=GufRey Rock, BBl=Black Butte I, Fang=Fang, SkCME=Sinker Creek Mouth East, TBtW=Tom Butte West, PrRpl=Priest Rapids I, JaNW=Jackass NW, RsDw=Rosie Draw, SKBl=Sinker Bluff, JBBGE=Jackass BBGE, FvrBU=Fever Basin Upstream, Unk=Unknown

[b] OTA abbreviations are as follows: S=nesting area within the OTA shadow, W=nesting area west of the OTA shadow, N=no known nesting area.

Table 8. Home range characteristics of paired prairie falcons in the SRBOPNCA determined from radiotelemetry in 1994. Distances are recorded in meters and home ranges are recorded in hectares. Table headings are abbreviated as follows: Hc-harmonic center, Ac-arithmetic activity center.

Nesting Area[a]	Sex	OTA[b]	N	Mean distance from: Nest	Hc	Ac	Hc-Nest	Max distance from: Nest	Hc	Ac	Harmonic Mean Home Range Max	95%	90%	50%	Convex Polygon Home Range Max	90%	70%	50%
SDDraw	F	W	55	7,641	1,833	7,042	5,805	21,870	17,100	17,490	65,210	51,680	38,357	5,780	52,430	33,930	14,430	6,450
SDTPol	F	W	63	7,480	2,487	5,987	174	17,250	17,340	15,680	49,344	24,953	21,235	4,128	28,950	23,270	12,780	5,688
MassFc	F	S	10	10,290	3,842	6,571	3,235	24,150	21,020	15,880	12,377	4,375	4,375	2,023	8,367	3,605	1,663	1,073
SlDrUS	F	S	135	10,070	2,600	5,258	9,735	21,560	12,790	13,400	46,180	26,428	21,999	5,594	33,420	18,790	10,430	5,814
BrCsUS	M	S	73	8,899	2,875	6,541	9,718	37,590	34,010	33,070	165,466	52,475	29,998	6,425	57,520	20,780	15,160	5,872
CtDS	F	S	127	11,050	2,536	6,494	11,665	26,670	22,780	21,130	114,921	42,125	31,721	8,235	49,380	32,760	14,220	2,856
PF1	F	W	85	8,308	1,667	7,332	1,177	29,680	29,360	29,020	154,959	47,553	28,889	6,783	58,480	25,680	11,380	3,437
OgdRk	F	W	40	3,207	538	3,841	990	13,870	14,810	12,290	14,665	11,992	9,856	372	9,403	6,003	413	124
SlDrUS	M	S	104	12,460	3,667	7,058	115,454	24,530	14,720	14,370	65,882	37,081	32,431	8,825	42,360	29,630	17,960	12,690
FBPtDS	M	S	36	12,880	6,006	8,805	4,775	26,290	21,900	16,290	48,924	42,508	30,679	9,889	52,000	34,780	20,760	12,410
CrDS	M	W	68	5,544	971	5,148	547	23,060	23,570	18,590	47,378	40,404	298,806	1,972	20,060	8,991	2,737	1,828
NoBdRk	M	S	68	8,927	2,969	8,012	1,411	31,050	29,690	28,100	131,643	86,879	51,849	7,927	66,510	32,230	12,090	8,469
DStUS	M	W	55	9,582	1,796	8,625	4,896	20,720	20,290	18,970	75,851	43,633	34,775	11,181	49,050	42,200	19,840	11,120
PerClf	F	W	51	9,454	1,924	6,380	11,065	24,090	26,130	24,470	97,797	42,713	23,986	5,966	41,650	19,700	9,580	6,091
Pwln	F	S	60	12,840	5,361	10,010	3,454	35,690	32,740	26,300	112,988	80,955	66,895	14,912	71,470	49,220	22,500	12,190
CSJ	M	S	59	8,971	2,978	6,471	6,239	23,560	17,400	16,210	51,040	38,341	32,385	7,234	33,160	22,080	10,920	7,420
HHPer	M	W	95	7,098	2,081	6,091	1,974	18,490	17,990	18,410	81,995	25,160	17,585	7,233	35,420	21,760	10,140	6,526
FvBs	F	S	21	13,120	5,450	8,331	6,892	24,450	19,150	17,680	37,666	31,693	22,071	4,329	34,250	24,420	14,290	8,888
CnTwDS	M	W	17	10,030	2,434	6,241	10,337	22,070	22,560	20,800	28,080	10,358	6,285	2,325	17,820	7,844	5,076	1,068
Fang	M	W	67		3,213	7,050			21,770	19,490	47,272	36,711	29,214	5,447	39,650	23,020	18,570	8,150
Ferry	F	W	89		2,962	7,096			20,140	16,230	70,219	49,357	38,869	10,929	50,580	36,450	17,930	9,336
OgRkUS	F	W	39		2,013	5,479			30,560	25,010	71,944	15,666	12,619	4,167	22,520	9,556	6,678	3,893
BlkBt	F	S	65	5,526	1,117	5,275	928	16,050	16,960	13,960	41,347	22,589	15,810	3,295	20,590	11,810	7,079	2,530
SnSbCvn	F	S	22	13,420	4,061	8,002	5,513	25,990	21,500	13,960	16,577	16,496	15,683	5,351	23,730	21,920	10,590	6,444
RslRT	M	S	137	11,730	2,210	4,799	9,189	21,440	14,540	16,130	58,382	27,201	21,343	5,961	30,290	19,230	8,896	4,958
Unk	M	N	53		4,274	10,670			25,990	20,810	93,080	62,790	45,697	11,919	64,500	46,920	32,710	12,810
HalTrl	M	W	56	7,590	1,954	6,241	8,573	24,520	30,180	24,910	75,611	40,766	23,680	4,028	28,950	13,010	7,002	3,294
Corral	M	W	71	6,252	2,440	4,739	3,826	20,880	21,130	19,970	61,990	24,002	15,747	2,828	29,160	10,470	4,596	2,927
SDRdSS	F	W	86	9,345	3,087	5,887	80,833	18,890	17,480	17,980	51,443	25,823	19,490	7,139	33,650	16,180	10,750	6,517
SlcDrw	M	W	17		3,677	20,950			5,717	14,790	15,468	8,131	5,603	1,243	11,400	7,519	4,245	2,379

[a] Nesting area names are as follows: Unk=Unknown, SDTPol=Swan Dam Three Poles, MassFc=Massacre Face, SlDUS=Swan I Draw Upstream, BrCsUS=Beercase Upstream, CltDS=Colt Downstream, PF1=PF1, OgdRk=Ogden Rock, SlDrUS=Swan I Draw Upstream, FBPtDS=Fever Basin Point DS, CrDS=Corral Downstream, NoBdRk=No Bird Rock, DStUS=Dedication Site Upstream, PerClf=Peregrine Cliff, Pwln=Powerline, CSJ=CSJ, HHPer=Hell Hole Peregrine, FvBs=Fever Basin, CnTwDS=Conning Tower Downstream, Fang=Fang, Ferry=Ferry, OgRkUS=Ogden Rock Upstream, BlkBt=Black Butte, SnSbCvn=San Sebastian Cavern, HalTrl=Halverson Trail, Corral=Corral, SDRdSS=Swan Dam Road South Side, SlcDrw=Slice Draw.

[b] OTA abbreviations are as follows: S=nesting area within the OTA shadow, W=nesting area west of the OTA shadow, N=no known nesting area.

Table 9. Home range characteristics of paired prairie falcons determined from radiotelemetry in 1994. Distances are recorded in meters and home ranges are recorded in hectares. Table headings are abbreviated as follows: Hr-sum of the reciprocal distance (d^{-1}) to each fix, divided by the number (n) of distances and then re-inverted (i.e., $n/\Sigma d^{-1}$), D-dispersion, Sk-skewness, K-kurtosis, Sp-spread.

Nesting Area[a]	Sex	OTA[b]	N	Home Range Shape						No. Locations inside:			
				Maximum Polygon width	Harmonic Mean					OTA(%)		Range Rd(%)	
					Hr	D	Sk	K	Sp				
SDDraw	F	W	55	31,160	1,867	4.146	3.56	11.26	5,072	5	(9)	0	(0)
SDTPol	F	W	63	24,220	2,528	2.13	5.16	3.94	4,674	24	(39)	0	(0)
MassFc	F	S	10	24,150	4,269	1.2	1.68	1.64	5,793	4	(44)	0	(0)
SIDrUS	F	S	135	24,380	2,620	2.00	0.52	3.37	4,406	46	(34)	0	(0)
BrCsUS	M	S	73	41,510	2,915	1.65	1.8	2.81	4,963	23	(32)	23	(32)
CltDS	F	S	127	36,800	2,556	4.78	3.88	9.90	5,293	50	(40)	46	(37)
PFl	F	W	85	38,960	1,687	2.70	8.37	6.57	4,100	18	(21)	1	(1)
OgdRk	F	W	40	15,490	552	1.91	8.83	4.17	1,203	3	(8)	0	(0)
SIDrUS	M	S	104	27,430	3,702	2.16	6.03	3.56	6,095	47	(46)	0	(0)
FBPtDS	M	S	36	27,820	6,178	1.06	1.06	1.46	8,470	10	(29)	1	(3)
CrlDS	M	W	68	24,140	985	3.05	15.46	7.86	2,537	7	(10)	0	(0)
NoBdRk	M	S	68	41,150	3,013	1.67	2.62	3.05	5,506	16	(24)	13	(19)
DStUS	M	W	55	32,780	1,829	5.26	3.80	18.39	6,399	9	(17)	1	(2)
PerClf	F	W	51	33,300	1,962	2.34	4.53	5.42	4,534	13	(26)	0	(0)
Pwln	F	S	60	40,760	5,452	1.05	1.38	1.60	8,287	26	(44)	9	(15)
CSJ	M	S	59	30,590	3,029	2.74	1.31	5.20	5,754	14	(24)	21	(36)
HHPer	M	W	95	27,760	2,103	4.09	5.62	9.5	4,886	16	(17)	0	(0)
FvBs	F	S	21	28,600	5,722	0.98	0.67	1.40	8,165	8	(40)	2	(10)
CnTwDS	M	W	17	27,950	2,586	1.12	1.17	1.92	4,443	3	(19)	0	(0)
Fang	M	W	67	28,550	3,262	2.07	2.68	3.39	5,346	18	(27)	0	(0)
Ferry	F	W	89	29,000	2,996	3.23	5.01	6.68	6,189	27	(30)	1	(1)
OgRkUS	F	W	39	31,190	2,066	3.26	10.40	6.13	3,882	0	(0)	0	(0)
BlkBt	F	S	65	22,370	1,134	4.24	15.68	13.05	3,487	14	(22)	11	(17)
SnSbCvn	F	S	22	25,990	4,255	1.55	2.76	2.44	6,688	6	(29)	0	(0)
RslRT	M	S	137	25,720	2,226	2.72	2.46	5.01	4,105	64	(47)	16	(12)
Unk	M	N	53	34,060	4,356	1.87	3.39	3.61	8,386	21	(40)	2	(4)
HalTrl	M	W	56	35,100	1,990	1.61	4.39	3.34	4,122	4	(7)	0	(0)
Corral	M	W	71	27,320	2,475	1.45	0.92	2.20	3,744	4	(6)	0	(0)
SDRdSS	F	W	86	26,790	3,123	2.23	0.40	3.58	5,013	24	(28)	0	(0)
SlcDrw	M	W	17	21,840	3,906	1.22	1.94	1.72	5,489	0	(0)	0	(0)

[a] Nesting area names are as follows: Unk=Unknown, SDTPol=Swan Dam Three Poles, MassFc=Massacre Face, SIDUS=Swan I Draw Upstream, BrCsUS=Beercase Upstream, CltDS=Colt Downstream, PFl=PFl, OgdRk=Ogden Rock, SIDrUS=Swan I Draw Upstream, FBPtDS=Fever Basin Point DS, CrlDS=Corral Downstream, NoBdRk=No Bird Rock, DStUS=Dedication Site Upstream, PerClf=Peregrine Cliff, Pwln=Powerline, CSJ=CSJ, HHPer=Hell Hole Peregrine, FvBs=Fever Basin, CrTwDS=Canning Tower Downstream, Fang=Fang, Ferry=Ferry, OgRkUS=Ogden Rock Upstream, BlkBt=Black Butte, SnSbCvn=San Sebastian Cavern, HalTrl=Halverson Trail, Corral=Corral, SDRdSS=Swan Dam Road South Side, SlcDrw=Slice Draw.

[b] OTA abbreviations are as follows: S=nesting area within the OTA shadow, W=nesting area west of the OTA shadow, N=no known nesting area.

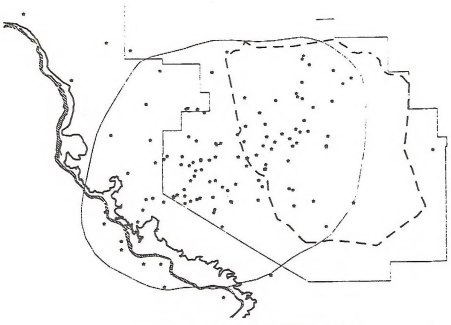
Figs. 2-13. Spatial use patterns of radio-tagged prairie falcons in 1994. Each bird was adequately sampled (see METHODS). Sex, nesting area, and breeding status for each individual are listed below each map. Individual locations are indicated with solid stars; aeries are indicated with open stars. The 95% core area determined by harmonic mean analysis is indicated by the thin, solid line. The Snake River (hatched area), north canyon edge (thick, solid line), OTA boundary (thin, dashed line) and Range Road (thick, dashed line) are shown for orientation, when present in the range. Each map is drawn to the same scale (1 : 288,600), and oriented with north at the top of the page, unless otherwise noted.

MALE - NO BIRD ROCK
OTA SHADOW
FAILED

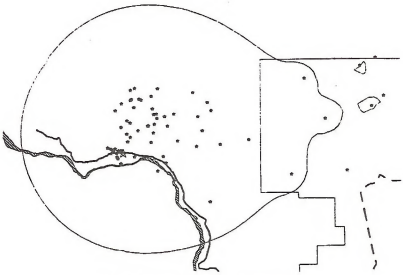
Figure 3.

FEMALE - POWERLINE
OTA SHADOW
SUCCESSFUL

Figure 4.

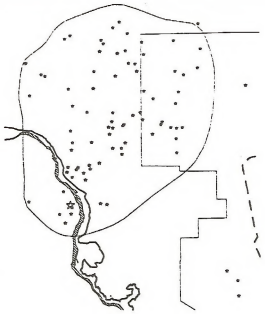


FEMALE - COLT DOWNSTREAM
OTA SHADOW
SUCCESSFUL

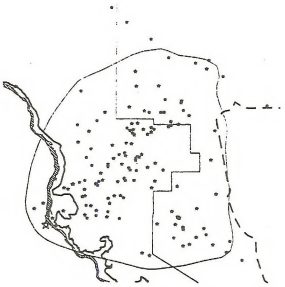


MALE - CORRAL DOWNSTREAM
WEST OF OTA SHADOW
FAILED

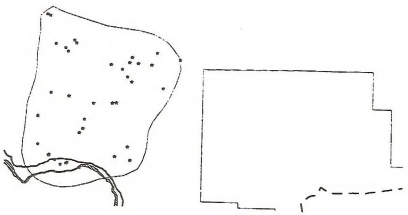
Figure 5.



FEMALE - SWAN DAM ROAD SOUTH SIDE
WEST OF OTA SHADOW
SUCCESSFUL

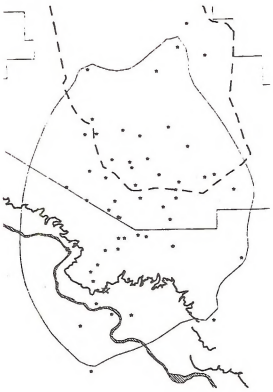


MALE - SWAN I DRAW UPSTREAM
OTA SHADOW
SUCCESSFUL

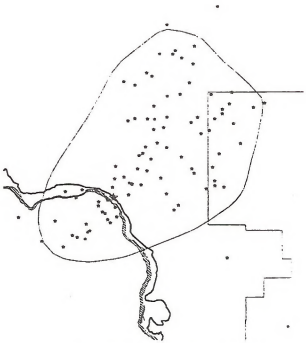


FEMALE - OGDEN ROCK UPSTREAM
WEST OF OTA SHADOW
NON-BREEDING

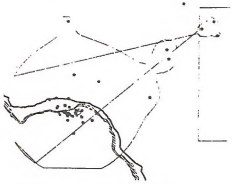
Figure 6.



MALE - CSJ
OTA SHADOW
SUCCESSFUL

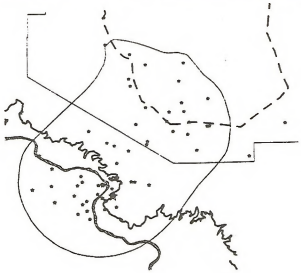


MALE - HELL HOLE PEREGRINE
WEST OF OTA SHADOW
SUCCESSFUL

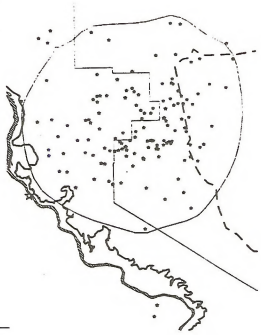


FEMALE - OGDEN ROCK
WEST OF OTA SHADOW
SUCCESSFUL

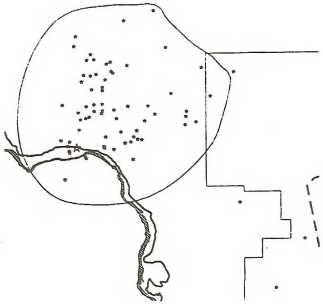
Figure 7.



FEMALE - BLACK BUTTE
OTA SHADOW
SUCCESSFUL

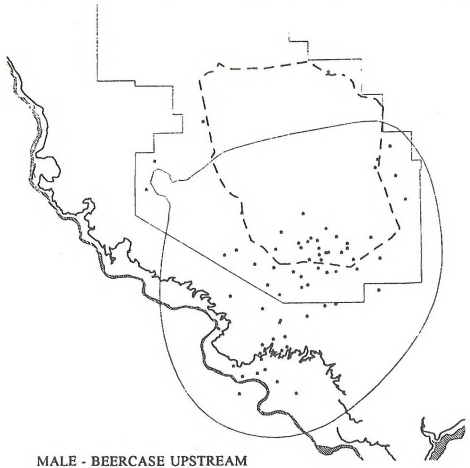


MALE - ROSIE I RED-TAIL
OTA SHADOW
SUCCESSFUL



MALE - CORRAL
WEST OF OTA SHADOW
SUCCESSFUL

Figure 8.


MALE - BEERCASE UPSTREAM
OTA SHADOW
FAILED

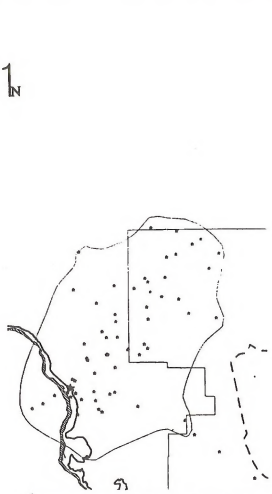
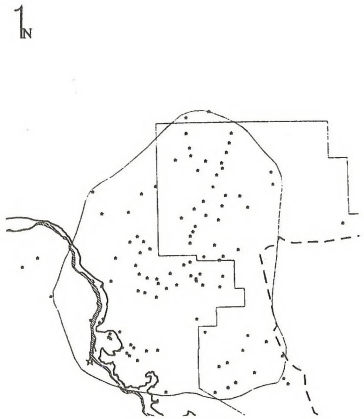

N
FEMALE - SWAN DAM THREE POLES
WEST OF OTA SHADOW
SUCCESSFUL

Figure 9.

FEMALE - SWAN DAM DRAW
WEST OF OTA SHADOW
SUCCESSFUL



FEMALE - FERRY
WEST OF OTA SHADOW
NON-BREEDING

Figure 10.

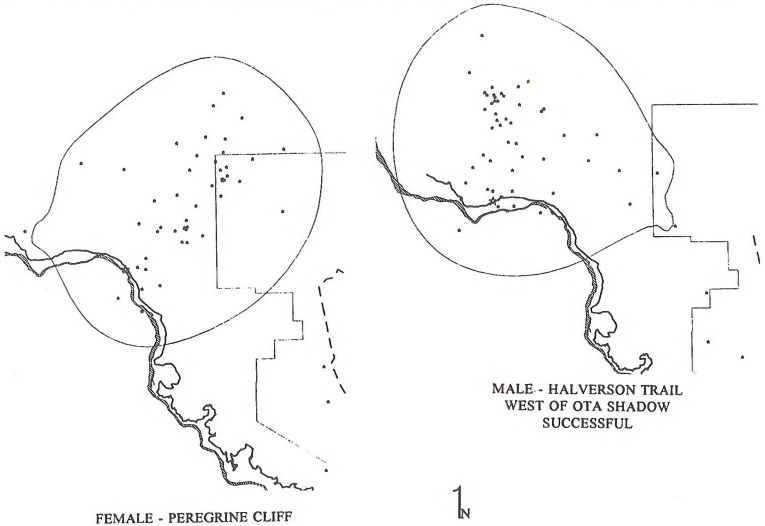

MALE - HALVERSON TRAIL
WEST OF OTA SHADOW
SUCCESSFUL
FEMALE - PEREGRINE CLIFF
WEST OF OTA SHADOW
SUCCESSFUL
N

Figure 11.

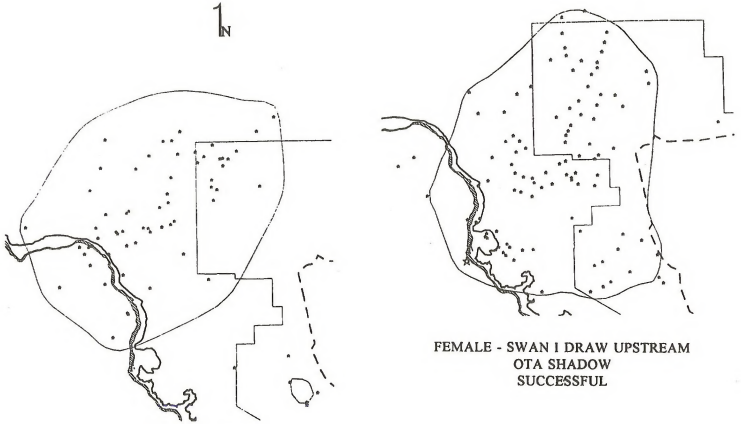

N
MALE - FANG
WEST OF OTA SHADOW
NON-BREEDING
FEMALE - SWAN I DRAW UPSTREAM
OTA SHADOW
SUCCESSFUL

Figure 12.

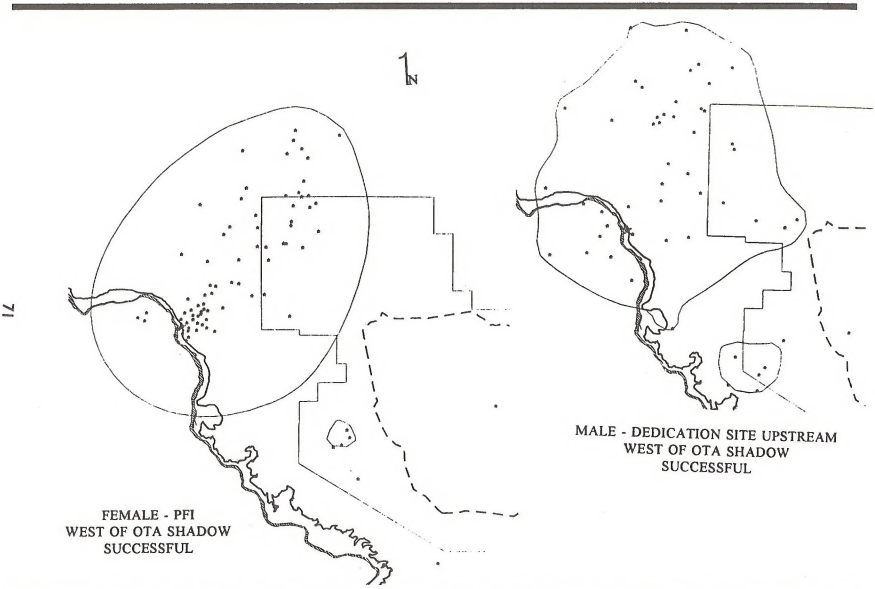

N
FEMALE - PFI
WEST OF OTA SHADOW
SUCCESSFUL
MALE - DEDICATION SITE UPSTREAM
WEST OF OTA SHADOW
SUCCESSFUL

Figure 13.

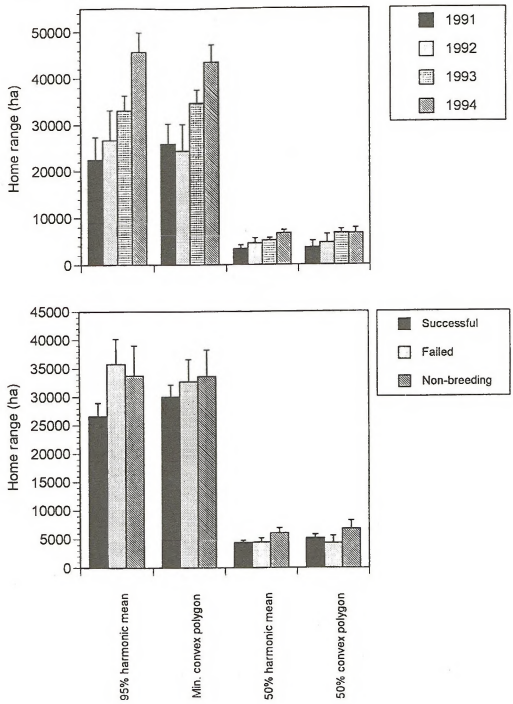


Fig. 14. Variation in home range by year and nesting status. Successful = breeders which fledged young successfully, Failed = breeders which laid eggs, but failed to fledge young, Non-breeders = birds with no known breeding status. Error bars are + 1 SE.

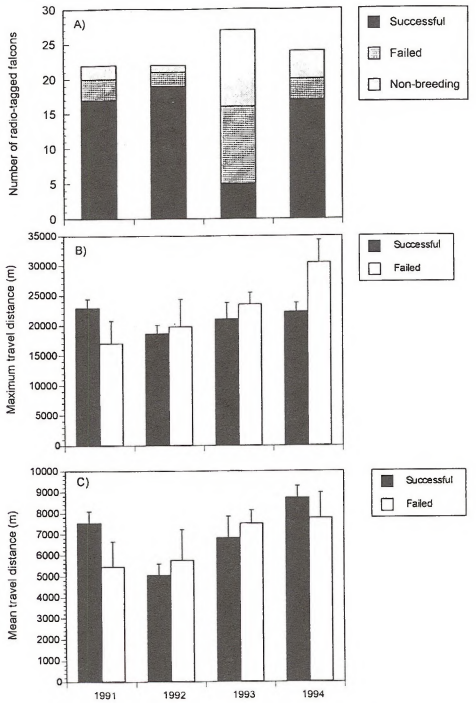


Fig. 15. Number of radio-tagged falcons by nesting success in each year (A), and maximum and mean travel distance from aerie for successful and failed falcons by year. Successful = breeders which fledged young successfully, Failed = breeders which laid eggs, but failed to fledge young, Non-breeders = birds with no known breeding status. Error bars are + 1 SE.

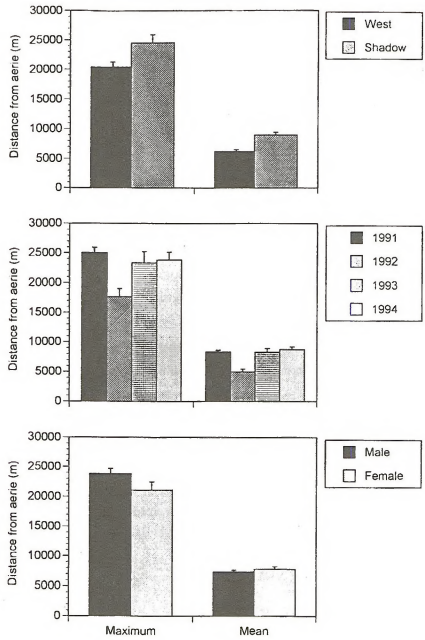


Fig. 16. Maximum and mean travel distances from aerie for falcons nesting west of the OTA and those nesting in the OTA shadow for each year, and male and female falcons. West = falcons nesting west of the OTA, Shadow = falcons nesting in the OTA shadow. Error bars are + 1 SE.

interaction between nest location, year, and sex: *Multivariate* $F_{(6,156)} = 6.47$, $P < 0.001$). For example, in 1991 females nesting west of the OTA had smaller 50% harmonic mean home ranges than did males, but females in the OTA shadow had larger ranges than did shadow males. In 1992, the completely opposite pattern was observed; west of OTA shadow males had smaller ranges than west of OTA shadow females, while shadow males had larger ranges than shadow females. The same patterns were generally observed in both 50% harmonic mean ranges and 50% convex polygon ranges.

Use of the OTA.--We obtained more falcon locations outside the OTA than inside the OTA in nearly all analyses comparing the 2 areas.

Examining the number of birds contacted hourly during 2-week periods shows that falcon activity increased until mid-morning, declined during mid-day, and then increased again mid-afternoon. This trend was particularly evident from May to early July in both OTA and non-OTA areas. Falcon numbers were usually highest outside the OTA in every 2-week period. Grouping fixes and contacts into 3 diurnal time periods within 3 seasons strengthened the conclusion that falcons were detected more often west of the OTA than inside the OTA (Fig. 18). We obtained significantly more fixes and contacted more birds per hour at sites west of the OTA than at sites inside the OTA (repeated measures ANOVA: main OTA effect for fixes: $\bar{x}_{west} = 1.23$, SE = 0.18; $\bar{x}_{shadow} = 0.81$, SE = 0.15; $F_{(1,24)} = 22.1$, $P = 0.002$; main OTA effect for

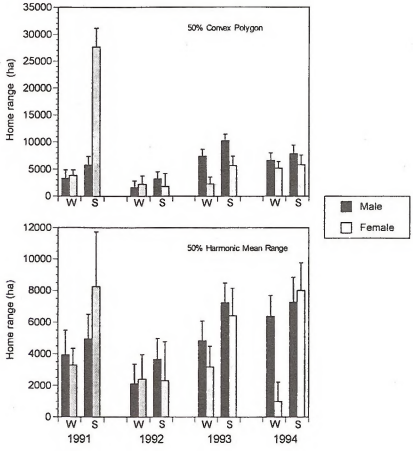


Fig. 17. Changes in 50% harmonic mean and 50% convex polygon home ranges by sex, nesting location, and year. W = falcons nesting west of the OTA, S = falcons nesting in the OTA shadow. Error bars are + 1 SE.

contacts: $\bar{x}_{west} = 6.19$, SE = 0.48; $\bar{x}_{shadow} = 4.06$, SE = 0.50; $F_{(1, 22)} = 27.8$, $P < 0.001$). Contacts varied significantly among years ($\bar{x}_{1991} = 3.6$, SE = 0.65; $\bar{x}_{1992} = 4.8$, SE = 0.51; $\bar{x}_{1993} = 6.1$ SE = 0.58, $\bar{x}_{1994} = 5.9$ SE = 0.98; repeated measures ANOVA, main effect of year: $F_{(3, 22)} = 9.1$, $P < 0.001$).

Use of the OTA varied by year, but falcons nesting in the OTA shadow always spent more time in the OTA than did falcons nesting west of the OTA. Males and females spent different percentages of time in the OTA, with females showing a dramatic drop in OTA use in 1992 (Fig. 19; MANOVA comparing % of time inside OTA and inside Range Road with OTA location, sex, and year: sex and year interaction- *Multivariate* $F_{(6,156)} = 2.64$, $P = 0.02$). In addition, use of the OTA declined for both shadow and west nesting falcons in 1992, with shadow falcons showing much higher use of the area in all years (Fig. 19; MANOVA comparing % of time inside OTA and inside Range Road with OTA location, sex, and year: OTA location and year interaction: *Multivariate* $F_{(6,156)} = 4.58$, $P < 0.001$). West of OTA falcons showed very little use of the area inside the Range Road.

Use of the area depended upon sex and nesting success of falcons. Non-nesting males and females who had failed at nesting spent much of their time in the OTA, although neither spent much time inside Range Road (Fig. 19; MANOVA comparing % of time inside OTA and inside Range Road with OTA location, sex, and nesting success: sex and success interaction- *Multivariate* $F_{(4,164)} = 2.63$, $P = 0.04$). As in the previous analysis, shadow birds used the OTA more than west birds (Fig. 19; MANOVA comparing % of time inside OTA and inside Range Road with OTA location, sex, and nesting success: OTA effect- $F_{(2, 82)} = 27.5$, $P < 0.001$. Percent in OTA: $\bar{x}_{shadow} = 36.6$, SE = 2.77, $\bar{x}_{west} = 15.81$, SE = 1.96. Percent in Range Road: : $\bar{x}_{shadow} = 12.15$, SE = 2.00, $\bar{x}_{west} = 1.94$, SE = 1.42).

Influence of military activity on ranging habits.--Firing on military ranges affected the distance falcons travelled from their aerie; this effect varied by year and by nesting location (Fig. 20). Falcons nesting in the OTA shadow ranged slightly farther on firing days than on non-firing days in both 1993 and 1994. Falcons nesting west of the OTA ranged farther on firing days in 1992 and farther on non-firing days in 1993. In 1991, there was no difference in travel distances, and in 1994 they ranged only slightly farther on firing days than on non-firing days. Falcons nesting in the OTA shadow ranged farther than west birds except on non-firing days in 1993 when west birds ranged nearly as far as shadow birds. The interaction between nesting location, firing, and year was highly significant (multi-way ANOVA testing nesting location, firing, and year against travel distance: $F_{(3, 5439)} = 6.37$, $n = 5455$, $P < 0.001$).

Shifts in falcon use of the area inside Range Road during firing varied by nesting location. Falcons nesting west of the OTA avoided the northern part of the firing area during firing, shifting their movements to the southern part of the study area outside the OTA ($X^2_{(3)} = 15.15$, $P = 0.01$). Falcons nesting in the OTA shadow did not significantly alter their movements within the Range Road on firing or non-firing days ($X^2_{(3)} = 6.59$, $P = 0.25$). Finer-scaled analyses are in progress to determine if firing on specific ranges at specific times influenced a falcon's estimated position inside Range Road on firing days.

Behavior of Nesting Prairie Falcons

Attendance in the Territory and at the Nest.--For all 4 years of the study, female falcons spent more of their time in their territories and close to their nests than did male falcons (*Multivariate* $F_{(4,72)} = 36.51$, $P < 0.001$). When nestlings were <21 days old, females were observed in their territory an average of 66.9% of the time ($n = 51$, SD = 8.1), but males were observed in their territory only 31.7% of the time ($n = 51$, SD = 14.9). Females were in their territories an average of 47.6% of the time ($n = 44$, SD = 19.6) when nestlings were 21-40 days old, whereas males were present 30.8% of the time ($n = 44$, SD = 15.6). When nestlings were <21 days old, females were seen within 5 m of the aerie 44.7% of the time ($n = 52$, SD = 21.6), and males were seen near the nest 9.1% of the time ($n = 52$, SD = 7.1). Both sexes reduced the time they spent at the nest as nestlings aged, but females still spent more of their time at the nest than did males (nestlings 21 - 40 days old: percentage of time females at nest = 7.8%, $n = 45$, SD = 8.5; for males = 3.6%, $n = 45$, SD = 5.8).

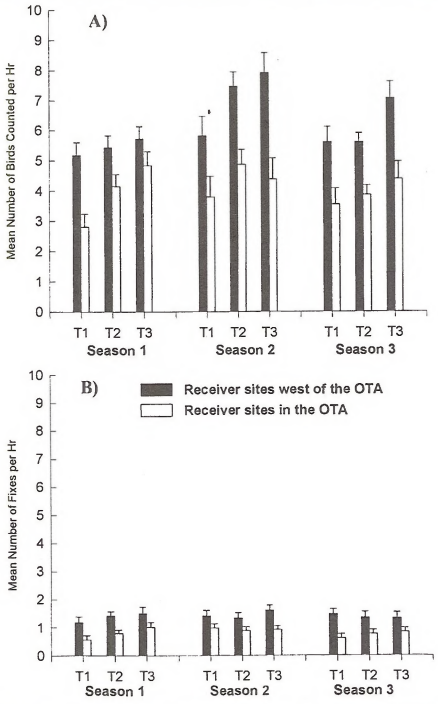


Fig. 18. Changes in radio-tagged falcon activity through the seasons (season 1 = 1 April - 15 May, season 2 = 16 May - 15 June, season 3 = 16 June - 1 August) and through the day (T1 = 0500 - 1000 hrs, T2 = 1100 - 1400 hrs, T3 = 1500 - 2100 hrs). Mean number of birds contacted (A) and mean number of fix locations within 3 km of site (B) + 1 SE are shown for 7 receiver sites in the OTA and 3 west of the OTA.

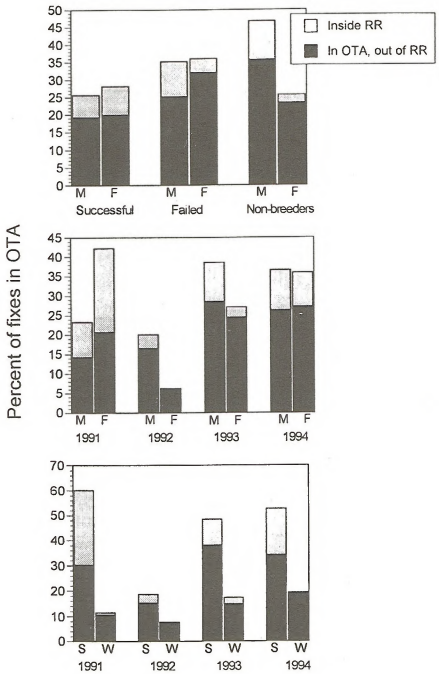


Fig. 19. Percent of total fix locations inside the OTA classified by sex, nesting status, year, and nest location. Fixes are classified as either inside Range Road, or outside Range Road but inside OTA. Combined, they equal total fixes inside OTA. M = male, F = female, Successful = breeders which fledged young successfully, Failed = breeders which laid eggs, but failed to fledge young, Non-breeders = birds with no known breeding status. S = falcons nesting in OTA shadow, W = falcons nesting west of the OTA shadow.

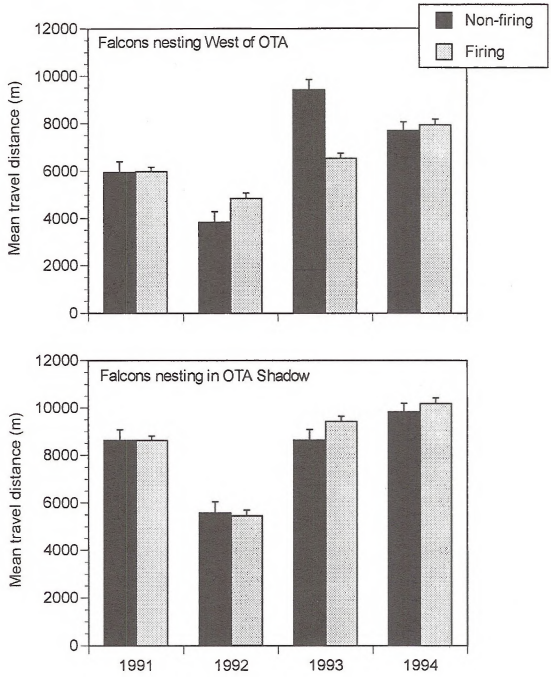


Fig. 20. Mean (+ 1 SE) travel distance from aerie for falcons nesting in the OTA shadow and west of the OTA on firing and non-firing days. Both sexes reduced the time they spent at the nest as nestlings aged, but females still spent more of their time at the nest than did males (nestlings 21 - 40 days old: percentage of time females at nest = 7.8%, n = 45, SD = 8.5; for males = 3.6%, n = 45, SD = 5.8).

Attendance in the territory was similar for parents nesting within the OTA shadow and for parents nesting west of the OTA during the early brood-rearing period (Fig. 21A; *Multivariate* $F_{(2,35)} = 2.64$, $P = 0.09$). However, year and proximity of the aerie to the OTA significantly influenced parental attendance during late brood-rearing (*Multivariate* $F_{(6,66)} = 2.56$, $P = 0.03$). OTA shadow parents spent less time in the territory in 1991 and 1993 (Fig. 21A). West of OTA females spent less time in the territory in 1993 and 1994, and males spent less time in the territory in 1994 (Fig. 21A). During the early brood-rearing period, parents—especially males—spent significantly more time in the territory in 1992 than in other years (*Multivariate* $F_{(6,70)} = 5.55$, $P < 0.001$; Fig. 21A).

Parents nesting in the OTA shadow did not differ in time spent in their territories or at their nests on training days versus non-training days (Table 10). Females, but not males, nesting west of the OTA spent significantly more time in their territories and at their nests on training days compared to non-training days (Table 10). Mean daily temperature, wind speed, and precipitation on training days versus non-training did not differ significantly (*Multivariate* $F_{(7,45)} = 0.83$, $P = 0.57$), suggesting that these factors did not influence our results.

During early brood-rearing, males and females nesting west of the OTA differed in time spent tending their nestlings from that spent by males and females nesting in the OTA shadow (*Multivariate* $F_{(2,36)} = 0.53$, $P = 0.59$; Fig. 21B). The time parents spent at their nests during the late brood-rearing period was significantly influenced by year and by proximity of their aerie to the OTA (*Multivariate* $F_{(2,68)} = 3.29$, $P < 0.007$). Parents nesting in the OTA shadow spent more time tending nestlings in 1993 and 1994, whereas parents nesting west of OTA spent more time at their nest in 1991 (Fig. 21B). Parental nest attendance during early brood-rearing did not differ among years of the study (*Multivariate* $F_{(6,72)} = 0.66$, $P = 0.69$).

Females whose nests had eggs that hatched later in the season spent less time in the territory when nestlings were <21 days old and when nestlings were 21 - 40 days old than females whose eggs hatched earlier in the season (Table 11). For males, only when nestlings were older did attendance significantly decrease with date of hatching (Table 11). Parental attendance at the nest was lower for nests that had later hatching dates than for nests that had earlier hatching dates. However, this pattern was only significant for males and females tending older nestlings (Table 11).

Parental attendance in the territory was not significantly correlated with brood size when we pooled data from all 4 years (Table 11). Although parents showed a slight tendency to spend more time at the nest as brood size increased, there was a significant relationship only for females tending older nestlings (Table 11).

Delivery of Prey Items.--Delivery rates of prey items to the nest by males and females was not influenced by the year of study or the proximity of nests to the OTA (Fig. 22A; 2-way interaction - nestlings <21 days old: *Multivariate* $F_{(6,72)} = 1.11$, $P = 0.36$; nestlings 21 - 40 days old: *Multivariate* $F_{(6,74)} = 0.44$, $P = 0.85$). All parents, regardless of proximity to the OTA, decreased their deliveries as nestlings aged (Fig. 22A). The rate of total prey delivered to the nest (male and female rates combined) was lower at nests hatching later in the season than at nests hatching earlier in the season (Table 11). Parents delivered more food to larger broods than to small broods (Table 11).

In 1992-1994, the average rate of fresh deliveries to the territory by males and females was similar for all territories regardless of proximity to the OTA and year (Fig. 22B; nestlings <21 days old: OTA: *Multivariate* $F_{(2,24)} = 1.24$, $P = 0.31$; year: *Multivariate* $F_{(4,48)} = 1.95$, $P = 0.12$; nestlings 21 - 40 days old: OTA: *Multivariate* $F_{(2,25)} = 0.61$, $P = 0.55$; year: *Multivariate* $F_{(4,50)} = 2.18$, $P = 0.09$). Parents nesting in the OTA shadow and parents nesting west of the OTA had similar total delivery rates to the territory (Fig. 22A; nestlings <21 days old: *Univariate* $F_{(1,25)} = 0.41$, $P = 0.53$; nestlings 21 - 40 days old: *Univariate* $F_{(1,26)} = 1.27$, $P = 0.27$). Total delivery rates also were not influenced by the year of study (nestlings <21 days old: *Univariate* $F_{(2,25)} = 1.27$, $P = 0.30$; nestlings 21 - 40 days old: *Univariate* $F_{(2,26)} = 0.84$, $P = 0.44$).

Date of hatching did not correlate significantly with the total rate of fresh prey delivered to the territory during early brood-rearing but was correlated

Table 10. Average differences in parental behavior at nests in the OTA shadow and west of the OTA on training versus non-training days in 1991-94. Observations were made within 1-5 days of each other at each nest once on training and once on non-training days. F-statistics are from repeated measure ANOVAs controlling for nestling age.

	Average Differences in Parental Behavior Training Minus No Training					
Parental Behavior	$\bar{x}$	*n*	SD	*F*	df	*P*
OTA Nests						
Time (%) in territory						
Male	0.65	18	10.58	1.27	1,16	0.28
Female	0.17	18	11.43	1.41	1,16	0.25
Time (%) at nest						
Male	-2.01	18	12.27	0.90	1,16	0.36
Female	3.29	18	12.39	4.02	1,16	0.06
Prey deliveries to nest/hr						
Male	-0.01	21	0.17	3.41	1,19	0.08
Female	-0.03	21	0.10	1.87	1,19	0.19
Total	-0.03	21	0.20	6.00	1,19	0.02
Prey deliveries to territory/hr						
Male	0.03	13	0.15	1.86	1,11	0.20
Female	0.03	13	0.09	0.17	1,11	0.69
Total	0.06	13	0.15	1.13	1,11	0.31
Caches/hr						
Male	0.00	13	0.03	0.63	1.11	0.45
Female	-0.01	13	0.10	0.12	1,11	0.74
Total	0.01	13	0.11	0.15	1,11	0.90
West of OTA Nests						
Time (%) in territory						
Male	2.95	17	7.22	2.21	1,15	0.16
Female	2.54	17	10.54	9.93	1,15	0.01
Time (%) at nest						
Male	1.92	17	6.26	1.70	1,15	0.21
Female	3.44	17	5.69	11.25	1,15	0.004
Prey deliveries to nest/hr						
Male	0.02	17	0.22	0.10	1,15	0.75
Female	0.02	17	0.11	0.04	1,15	0.84
Total	0.03	17	0.22	0.17	1,15	0.68
Prey deliveries to territory/hr						
Male	0.02	16	0.20	1.98	1,14	0.18
Female	0.01	16	0.13	4.53	1,14	0.05
Total	0.02	16	0.24	0.03	1,14	0.87
Caches/hr						
Male	0.02	16	0.07	1.71	1,14	0.21
Female	-0.04	16	0.17	0.96	1,14	0.35
Total	0.02	16	0.10	0.85	1,14	0.37

Table 11. Pearson correlations between hatching date, brood size, and parental behavior at all prairie falcon nests in the SRBOPNCA where intensive nest observation took place in 1991-94. Percentages were transformed prior to analysis (arcsine of square root).

	Hatching Date			Brood Size		
Parental Behavior	*r*	*n*	*P*	*r*	*n*	*P*
Percentage of Time in Territory						
Male (nestlings <21 days old)	-0.10	51	0.49	-0.03	46	0.86
(nestlings 21-40 days old)	-0.40	45	0.01	-0.24	44	0.11
Female (nestlings <21 days old)	-0.35	51	0.01	0.12	46	0.42
(nestlings 21-40 days old)	-0.38	45	0.01	-0.19	44	0.21
Percentage of Time at Nest						
Male (nestlings <21 days old)	-0.11	52	0.43	0.06	47	0.69
(nestlings 21-40 days old)	-0.40	46	0.01	0.19	45	0.21
Female (nestling <21 days old)	-0.16	52	0.26	0.20	47	0.18
(nestlings 21-40 days old)	-0.41	46	0.00	0.29	45	0.05
Prey Deliveries to Nest per Hr						
Male (nestlings <21 days old)	-0.21	52	0.13	0.12	47	0.42
(nestlings 21-40 days old)	-0.16	49	0.29	0.23	48	0.12
Female (nestlings <21 days old)	-0.31	52	0.03	0.36	47	0.01
(nestlings 21-40 days old)	-0.34	49	0.02	0.20	48	0.18
Total (nestlings <21 days old)	-0.33	52	0.02	0.32	47	0.03
(nestlings 21-40 days old)	-0.37	49	0.01	0.33	48	0.02
Prey Deliveries to Territory per Hr						
Male (nestlings <21 days old)	-0.33	38	0.05	0.10	33	0.58
(nestlings 21-40 days old)	-0.21	35	0.24	0.19	34	0.29
Female (nestlings <21 days old)	0.03	38	0.88	0.17	33	0.34
(nestlings 21-40 days old)	-0.26	35	0.13	0.09	34	0.63
Total (nestlings <21 days old)	-0.29	38	0.08	0.19	33	0.28
(nestlings 21-40 days old)	-0.34	35	0.05	0.21	34	0.23
Caches per Hr						
Male (nestlings <21 days old)	-0.22	38	0.18	0.15	33	0.42
(nestlings 21-40 days old)	0.14	35	0.42	-0.06	34	0.74
Female (nestlings <21 days old)	-0.23	38	0.17	-0.06	33	0.75
(nestlings 21-40 days old)	-0.15	35	0.93	0.03	34	0.86
Total nestlings <21 days old)	-0.33	38	0.04	0.05	33	0.80
(nestlings 21-40 days old)	0.06	35	0.72	-0.01	32	0.95

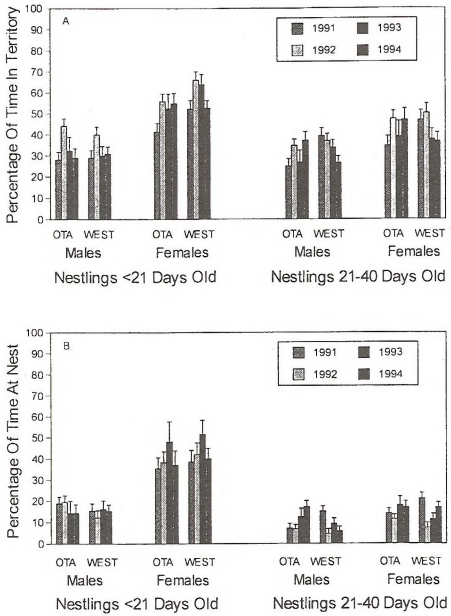


Fig. 21. Territory (A) and nest (B) attendance of prairie falcons nesting in the OTA shadow vs. nesting west of the OTA shadow, 1991-1994. Adjusted least square means (+ 1 SE) for behaviors are presented separately for parents tending nestlings <21 days old and those tending 21 - 40 day old nestlings. Samples sizes, for the number of aeries where nesting adults were observed, are as follows: (A) For nestlings <21 days old: OTA shadow nests - 1991 $n = 7$, 1992 $n = 7$, 1993 $n = 2$, 1994 $n = 4$; West of OTA nests - 1991 $n = 6$, 1992 $n = 8$, 1993 $n = 4$, 1994 $n = 8$. For nestlings 21 - 40 days old: OTA shadow nests - 1991 $n = 6$, 1992 $n = 8$, 1993 $n = 2$, 1994 $n = 4$; West of OTA nests - 1991 $n = 5$, 1992 $n = 7$, 1993 $n = 5$, 1994 $n = 7$; (B) All sample sizes are the same as above except for 1991 OTA shadow nests: for nestlings <21 days old $n = 8$, for nestlings 21 - 40 days old $n = 7$.

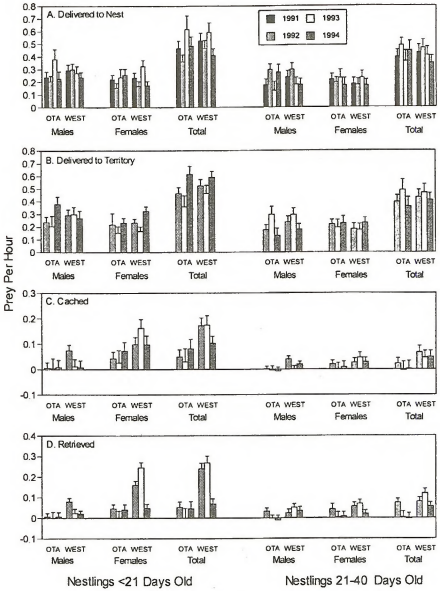


Fig. 22. Food handling behaviors by prairie falcons nesting in the OTA shadow vs. west of the OTA, 1991-1994. Delivery of all items to the nestlings (A), delivery of fresh items into the territory (B), caching (C), and retrieval (D) of all items are plotted as rates per hour of observation. Adjusted least square means (+1 SE) for behaviors are presented separately for parents tending nestlings <21 days old and those tending 21 - 40 day old nestlings. Delivery of items into the territory are minimum rates because items not able to be classified as fresh or old are not included. Likewise, retrievals do not include items not known to be previously cached and are therefore minimum rates. Sample sizes, for the number of aeries where male and female food handling behaviors were observed, are presented below. For 1991, only deliveries to the nest were calculated. For nestlings <21 days old: OTA shadow nests - 1991 $n = 8$, 1992 $n = 7$, 1993 $n = 2$, 1994 $n = 4$; West of OTA nests - 1991 $n = 6$, 1992 $n = 8$, 1993 $n = 4$, 1994 $n = 8$. For nestlings 21 - 40 days old: OTA shadow nests - 1991 $n = 8$, 1992 $n = 8$, 1993 $n = 3$, 1994 $n = 4$; West of OTA nests - 1991 $n = 6$, 1992 $n = 7$, 1993 $n = 5$, 1994 $n = 7$.

negatively with fresh prey deliveries when nestlings were older (Table 11). Brood size did not influence total fresh delivery rate (Table 11).

Caching and retrieval rates in 1992-1994 were higher at nests west of the OTA than at nests in the OTA shadow (Fig. 22C, D). Caching occurred more frequently at sites west of the OTA than at sites in the OTA shadow when nestlings were <21 days old (*Multivariate* $F_{(2,24)} = 4.58$, $P = 0.02$), but not when nestlings were older (*Multivariate* $F_{(2,25)} = 2.41$, $P = 0.11$). Total caching rates were significantly higher at nests west of the OTA than at nests in the OTA shadow when nestlings were younger (*Univariate* $F_{(1,25)} = 9.38$, $P = 0.01$) and when nestlings were older (*Univariate* $F_{(1,26)} = 4.26$, $P = 0.05$). The year of study had no influence on the total caching rate when nestlings were <21 days old (*Univariate* $F_{(2,25)} = 0.17$, $P = 0.85$) or when nestlings were 21 - 40 days old (*Univariate* $F_{(2,26)} = 0.40$, $P = 0.68$).

Cache retrievals differed significantly among years and were influenced by proximity of nests to the OTA when nestlings were <21 days old (2-way interaction: *Multivariate* $F_{(4,48)} = 5.14$, $P = 0.002$). Parents nesting west of the OTA retrieved caches at a higher rate than parents nesting in the OTA shadow in all 3 years (Fig. 22D). Parents with nests west of the OTA retrieved more caches when nestlings were 21 - 40 days old than did parents with nests in the OTA shadow (*Multivariate* $F_{(2,25)} = 4.56$, $P = 0.02$). Retrieval rates for males and females combined were influenced significantly by year of study and by proximity of the nest to the OTA (2-way interaction for nestlings <21 days old: *Multivariate* $F_{(2,25)} = 7.12$, $P = 0.004$). Total retrieval rates were lower in all years at nests in the OTA shadow than at nests west of the OTA. Total rates also were lower at nests west of the OTA in 1994 than in 1992 or 1993 but were lowest in 1993 for nests in the OTA shadow. For nestlings 21 - 40 days old the interaction between year and OTA was not significant (*Multivariate* $F_{(2,26)} = 3.12$, $P = 0.06$), but retrieval rates showed the same pattern as when nestlings were younger.

The occurrence of military training on the OTA ranges rarely influenced delivery rates of prey items by males and females to OTA shadow and West of OTA nests (Table 12). The most significant finding was that total delivery rates to OTA shadow nests were greater on non-training days than on training days (Table 12). In contrast, the rate of fresh prey items delivered to the territory by females nesting west of the OTA was higher on training days (Table 12). Caching rates at nests in the OTA shadow or at nests west of the OTA did not differ on training versus non-training days (Table 12).

The proportion of prey types delivered fresh to the territory differed significantly among years ($G^2_{(4)} = 86.6$, $P < 0.001$). Parents delivered more Townsend's ground squirrels in 1992 than in 1993 or 1994 (Fig. 23). Conversely, more reptiles and birds were delivered in 1993 and 1994 than in 1992 (Fig. 23). Year also interacted significantly with OTA ($G^2_{(2)} = 17.8$, $P < 0.005$). Parents nesting in the OTA shadow delivered more reptiles and birds to the territory than did parents nesting west of the OTA in all 3 years of study, but the difference was most striking in 1993 (Fig. 24). Additionally, OTA shadow parents delivered fewer Townsend's ground squirrels than did west of OTA parents in 1992 and 1993 (Fig. 24).

A bimodal pattern of prey delivered to the nestlings was evident and was similar at nests in the OTA shadow and nests west of the OTA (Likelihood ratio test on categories in Fig. 25B, F; lumping 14 - 15 hr after sunrise: $G^2_{(14)} = 15.03$, $P = 0.38$). Prey deliveries peaked 3 to 5 hours after sunrise, declined during midday, and then climbed to peak again 4 to 5 hours before sunset (Fig. 25B, F). Delivery rates to the territory also showed a bimodal distribution for nests in the OTA shadow and west of the OTA (Fig. 25A, E). Prey retrieval from caches was highest early in the morning and prior to the afternoon peak of fresh items delivered to the territory (Fig. 25D, H).

Military Training and Raptor Abundance

Military training in 1994 differed from previous years. Overall, there were as many training days as in previous years, but the numbers of personnel and vehicles were most similar to 1991 (Fig. 26). As in 1991, total numbers of raptors observed was low (Figs. 27A, 28); there was no correlation between numbers of raptors observed on the firing ranges and the level of activity on the OTA ($r = -0.17$, $n = 31$, $P = 0.25$).

Table 12. Pearson correlations between age of prairie falcon nestlings (days) and parental behavior at nests inside the OTA shadow and west of the OTA shadow in 1991-94. Percentages were transformed prior to analysis (arcsine of square root).

	Nestling Age					
	OTA shadow nests			West of OTA nests		
Parental Behavior	r	n	P	r	n	P
Time (%) in territory						
Male	-0.23	(82)	0.04	-0.12	(94)	0.24
Female	-0.48	(82)	<0.001	-0.56	(94)	<0.001
Time (%) at nest						
Male	-0.50	(84)	<0.001	-0.54	(94)	<0.001
Female	-0.85	(84)	<0.001	-0.78	(94)	<0.001
Prey deliveries to nest per hr						
Male	0.04	(89)	0.72	-0.21	(94)	0.04
Female	0.001	(89)	0.99	0.04	(94)	0.73
Total	0.31	(89)	0.77	-0.13	(94)	0.23
Prey deliveries to territory per hr						
Male	0.17	(55)	0.22	-0.28	(76)	0.01
Female	0.31	(55)	0.02	0.25	(76)	0.03
Total	0.35	(55)	0.01	-0.10	(76)	0.39
Caches per hr						
Male	-0.12	(55)	0.39	-0.20	(76)	0.08
Female	-0.32	(55)	0.02	-0.55	(76)	<0.001
Total	-0.33	(55)	0.01	-0.56	(76)	<0.001

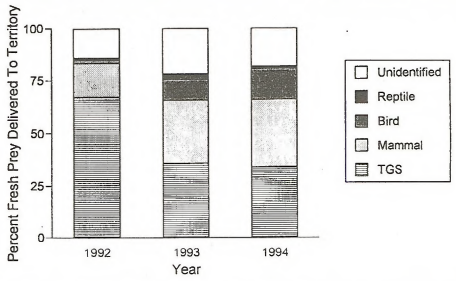


Fig. 23. Percentage of fresh prey items delivered by adult prairie falcons to their territories in 1992, 1993, and 1994. Unidentified prey items are presented here but were excluded from the analysis. Sample sizes for prey types are as follows: For 1992 - TGS n = 177, mammal n = 42, bird n = 4, reptile n = 3, unidentified n = 37; For 1993 - TGS n = 77, mammal n = 65, bird n = 21, reptile n = 6, unidentified n = 47; For 1994 - TGS n = 86, mammal n = 81, bird n = 37, reptile n = 3, unidentified n = 46.

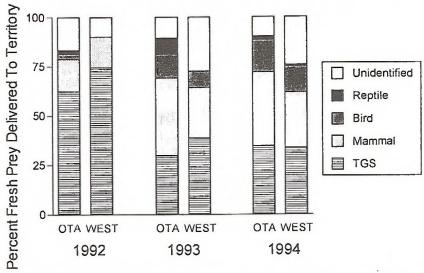


Fig. 24. Percentage of fresh prey items delivered by adult prairie falcons to their territories in the OTA shadow and west of OTA in 1992, 1993, and 1994. Unidentified prey items are presented here but were excluded from the analysis. Sample sizes for prey types are as follows: In 1992 for OTA shadow territories: TGS $n = 96$, mammal $n = 25$, bird $n = 4$, reptile $n = 3$, unidentified $n = 26$; for West of OTA territories: TGS $n = 81$, mammal $n = 17$, bird $n = 0$, reptile $n = 0$, unidentified $n = 11$; In 1993 for OTA shadow territories: TGS $n = 22$, mammal $n = 29$, bird $n = 9$, reptile $n = 6$, unidentified $n = 8$; for West of OTA territories: TGS $n = 55$, mammal $n = 36$, bird $n = 12$, reptile $n = 0$, unidentified $n = 39$; In 1994 for OTA shadow territories: TGS $n = 38$, mammal $n = 41$, bird $n = 18$, reptile $n = 2$, unidentified $n = 11$; for West of OTA territories: TGS $n = 48$, mammal $n = 40$, bird $n = 19$, reptile $n = 1$, unidentified $n = 35$.

Paired Observations at Ranges.--Our experiment using 4 tank and artillery ranges revealed no difference in the number of raptors observed on days when firing occurred versus days when firing did not occur, despite timing within the season (early season: $F_{(1,2)} = 1.32$, $P = 0.37$; mid-season: $F_{(1,2)} = 0.13$, $P = 0.75$; late season: $F_{(1,2)} = 0.26$, $P = 0.66$). Unlike previous years, mean abundances of raptors observed were relatively uniform throughout the season and throughout the day ($F_{(2,1)} = 0.87$, $P = 0.60$).

The repeated measures analyses presented above did not directly account for the influence of temperature and wind speed on raptor abundance. However, analysis of average temperature and wind speed throughout the day on firing and non-firing days suggests that these factors did not confound our results. Patterns of temperature increase were similar on firing and non-firing days (2-way interaction between military activity and time of day: multivariate $F_{(3,9)} = 0.65$, $P = 0.58$). Wind speeds also did not vary significantly on firing versus non-firing days (2-way interaction between military activity and time of day: $F_{(3,6)} = 2.44$, $P = 0.26$).

There was a differential effect of military activity among the seasons and throughout the day among the 4 years of the study (Fig. 29; 4-way interaction among season, military activity, time of day, and year: $F_{(18,23)} = 2.61$, $P = 0.02$). Overall, military effects were more evident late in the day than early in the day, more during the early and mid-seasons than late in the season, and more in 1992 than in 1991, 1993, or 1994.

Prairie falcon counts were not influenced by military training in the same way as were counts of all raptors. The influence of military activity on prairie falcons did not vary among years (4-way interaction among season, military activity, time of day, and year: $F_{(18,23)} = 1.133$, $P = 0.383$; 3-way interaction among season, military activity, and year: $F_{(6,24)} = 2.115$, $P = 0.089$). Combining prairie falcon counts on ranges from 1991-94, we observed fewer prairie falcons per hour when there was training on the range than when there was no

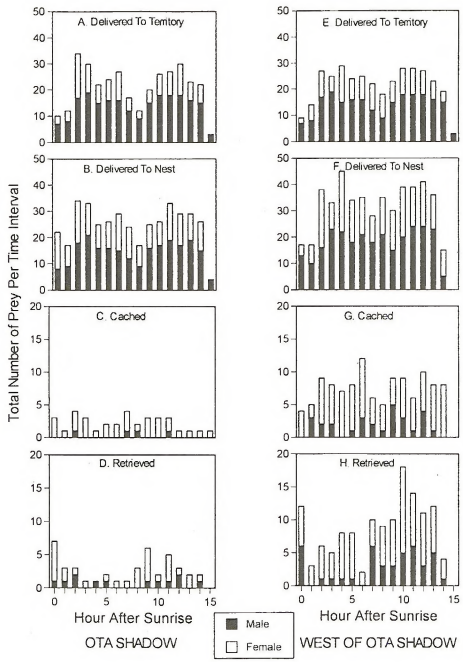


Fig. 25. Timing of the total number of prey items delivered to the nest (1991-1994) and to the territory, cached, and retrieved (1992-1994) by adult prairie falcons. The total number of items is plotted which is sensitive to observation time and is not comparable between OTA shadow sites and west of OTA shadow sites. Relative differences throughout the day are comparable because each hour was observed the same number of times.

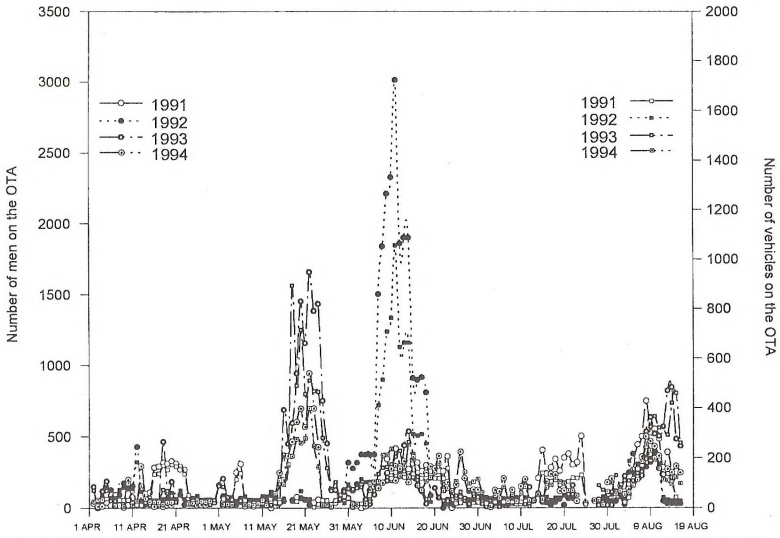


Fig. 26. Level of military activity on the OTA in 1991, 1992, 1993, and 1994. Relative intensity of military use of the OTA is represented by counts of men and vehicles on the OTA.

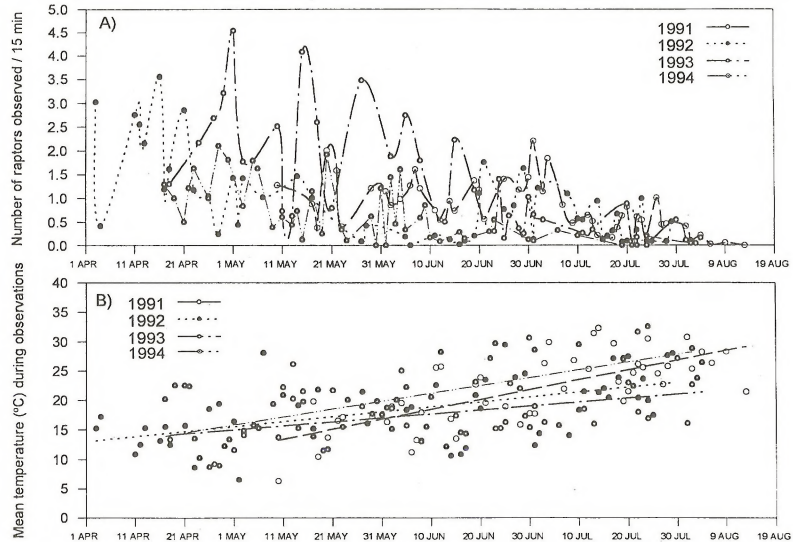


Fig. 27. Raptor abundance (A), and temperature (B) in 1991, 1992, 1993, and 1994. Relative raptor abundance is plotted as the average number of raptors observed per 15 min on all ranges observed on a given day (A). Hourly temperatures were obtained from the National Weather Service, and averaged over the observation period (B).

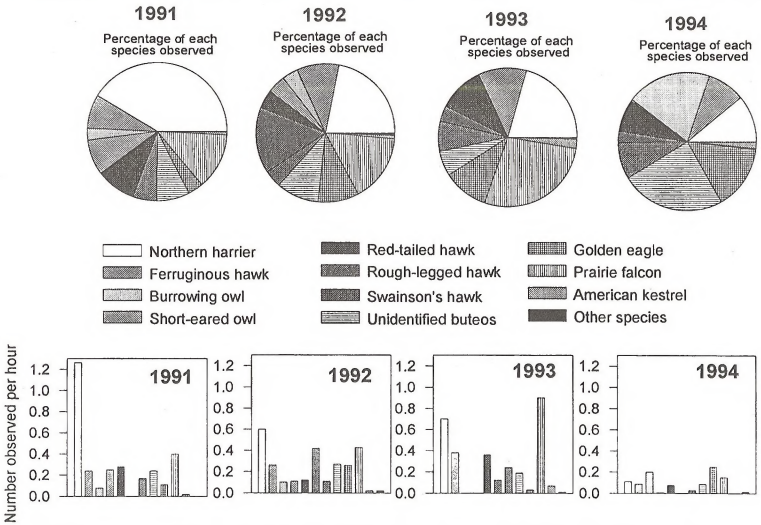


Fig. 28. Species composition of raptors observed during observations at military firing ranges in 1991, 1992, and 1993. Percentages are plotted as pieces of a pie totalling 100% of all raptors observed in the given year. Actual numbers of each species observed per hour are represented by bars of corresponding pattern.

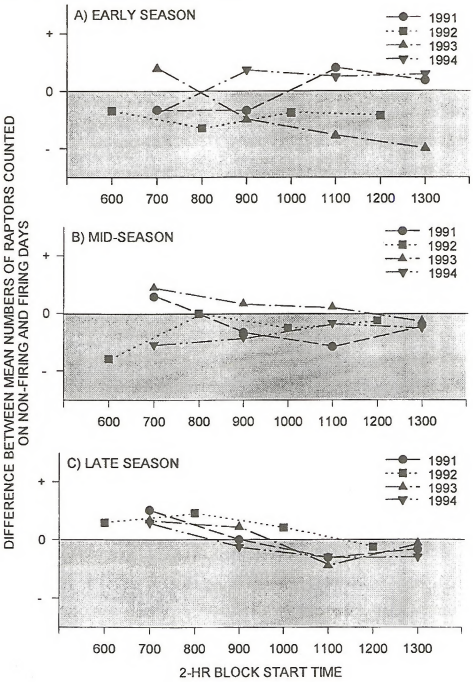


Fig. 29. Difference between mean numbers of raptors counted on tank firing, small arms firing, and artillery ranges throughout the day in each of 3 seasons in 1991-93. Portions of the lines that are in the shaded area indicate a military effect. Points on the line between the shaded and unshaded areas indicate no effect of military training. Portions of the lines that are out of the shaded area indicate an enhancement in the number of raptors observed when training occurred. The range of dates used for each season (A, B, C) is given in Fig. 28.

training ($F_{(1,14)} = 6.28$, $P = 0.03$). However, there was no significant effect of firing on the numbers of prairie falcons observed within any season (Fig. 29; early season: $F_{(1,18)} = 2.01$, $P = 0.17$; mid-season: $F_{(1,19)} = 1.23$, $P = 0.28$; l ate season: $F_{(1,19)} = 1.82$, $P = 0.19$). Within the early season, prairie falcon counts varied between years ($F_{(3,18)} = 3.70$, $P = 0.031$). During the mid-season and late season, counts did not differ between years (mid-season: $F_{(3,19)} = 1.13$, $P = 0.36$; late season: $F_{(3,19)} = 1.6$, $P = 0.22$).

Observations on 1 range (range 10) throughout the day in 1992-1994 suggested that we were not missing any significant interaction between raptor abundance and military activity by scheduling most of our observations in the morning and afternoon. In fact, we observed *fewer* raptors using Range 10 after our typical observation period under all conditions and over all years of study ($t = 2.43$, 16 df, $P = 0.03$). Mean differences between raptor abundance on Range 10 on firing versus non-firing days did not differ between our typical observation period and the evening observation period over the seasons and years of study ($t = -0.14$, 7 df, $P = 0.89$).

Observations at All Ranges.--There was no difference in raptor activity associated with military activity at 8 ranges and 4 bivouac/maintenance sites in 1994 (Fig. 30A; $F_{(3,126)} = 1.39$, $P = 0.23$). There also was no difference in raptor activity when we compared average activity on days with no training, "quiet" tank training, and Range Road traffic to activity on days with tank, mortar, or small arms firing ($F_{(1,130)} = 0.48$, $P = 0.49$). Raptor abundance on firing ranges differed significantly among years, but the difference was not influenced by the military training regime (Fig. 30A; 2-factor ANOVA: main effect of year: : $F_{(1,556)} = 5.24$, $P = 0.02$; interaction between year of study and firing vs quiet training: $F_{(3,556)} = 1.23$, $P = 0.29$). Over the 4 years of study, firing live ammunition on training ranges tended to reduce the number of raptors observed ($F_{(3,556)} = 2.55$, $P = 0.06$). Temperature was a significant covariate in all analyses of influence of military activity on numbers of raptors observed (all military activity: $F_{(1,126)} = 7.74$, $P < 0.001$; lumped activity: $F_{(1,130)} = 27.58$, $P < 0.001$; lumped activity 1991-94: $F_{(1,556)} = 73.30$, $P < 0.001$). Wind speed contributed to the explanation of raptor activity only in the analysis of firing vs. quiet training in all years ($F_{(1,556)} = 6.32$, $P = 0.01$).

The consistency of military activity during our samples of raptor abundance did not influence the number of raptors observed in 1994. We counted similar numbers of raptors when the range was completely or partially inactive and when it was active throughout the survey (Fig. 30B; $F_{(2,130)} = 0.70$, $P = 0.50$). Over the 4 years of study, raptor abundance decreased significantly as the consistency of t raining increased (Fig. 30B; $F_{(2,556)} = 3.43$, $P = 0.03$). Temperature was a significant covariate in both analyses (1994: $F_{(1,130)} = 27.92$, $P < 0.001$; 1991-94: $F_{(1,556)} = 89.20$, $P < 0.001$), but wind speed was a significant covariate only in the analysis of 1991-94 combined data ($F_{(1,556)} = 6.38$, $P = 0.01$).

Military Training and Raptor Behavior.--As in previous years, the 4 major groups of raptors using the training ranges exhibited species-typical repertoires of behavior in 1994 (Fig. 31). To test the hypothesis that military training did not influence raptor behavior, we compared behavior in versus out of the firing fan on firing versus non-firing days in 1994 and then determined how behaviors varied among the 4 years of the study (Fig. 32; 4-way interaction among behavior, location in or out of the fan, activity on the range, and year in log-linear models of 9 behavioral categories).

The level of military activity on the firing ranges influenced falcon behavior in 1994 (Fig. 32B; 2-way interaction between firing activity and behavior: $G^2_{(8)} = 15.31$, $P < 0.06$). They were observed flying low and perching less often in the fan on training days, and more often observed travelling high and soaring. We saw no attacks in the firing fan on training days. Falcons behaved differently in and out of the firing fan in response to training activities in each year of study (Fig. 32B; 4-way interaction among firing activity, location, behavior, and year: $G^2_{(14)} = 38.65$, $P = 0.03$). In 1994, falcons were observed perched less often than in any previous year. Frequencies of common behaviors varied with respect to firing in the different years (3-way interaction among firing activity, behavior and year: $G^2_{(24)} = 49.82$, $P < 0.005$), but the frequencies did

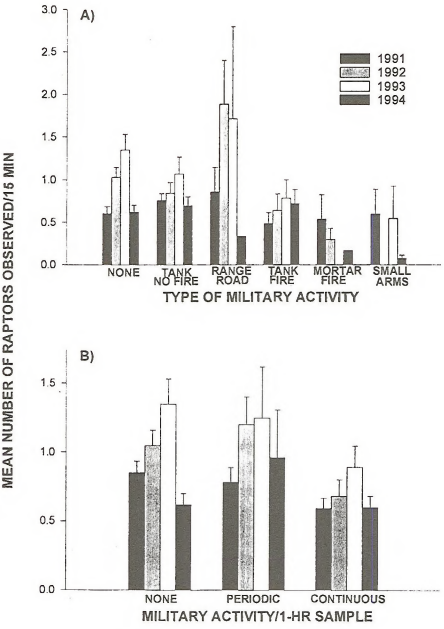


Fig. 30. Average number of raptors (+ 1 SE) observed on military firing ranges under different firing regimes in 1991-1994. Type of military activity on the range (A) was categorized as: none = no activity, Tank/ no fire = driving, preparing, laser-training tanks, Range Road = convoy traffic on Range Road, tank/fire = tanks shooting main turret gun and / or machine guns, mortar fire = artillery firing, and small arms = M-60, M-16, M-40 rifle and .45 pistol firing. Military activity per hr (B) was categorized as none = no activity, partial = activity punctuated by periods of inactivity, and complete = sustained activity during entire hour. No mortar training was observed in 1993.

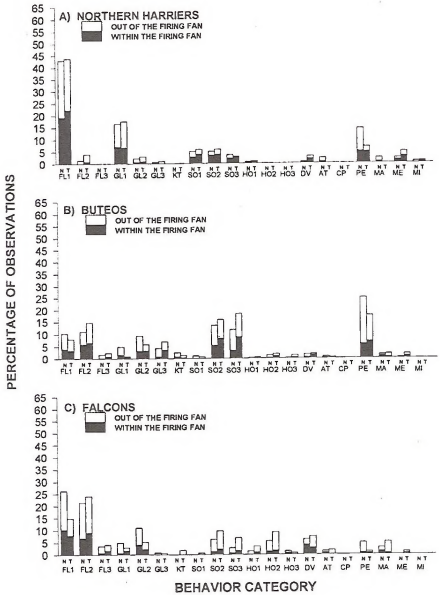

A) NORTHERN HARRIERS
OUT OF THE FIRING FAN
WITHIN THE FIRING FAN
B) BUTEOS
OUT OF THE FIRING FAN
WITHIN THE FIRING FAN
C) FALCONS
OUT OF THE FIRING FAN
WITHIN THE FIRING FAN
PERCENTAGE OF OBSERVATIONS
BEHAVIOR CATEGORY
N T
FL1 FL2 FL3 GL1 GL2 GL3 KT SO1 SO2 SO3 HO1 HO2 HO3 DV AT CP PE MA ME MI

Fig. 31. Full repertoire of behaviors recorded for 3 groups of raptors utilizing the military firing ranges in 1994. Percentage use of each behavior is compared on non-training days (N) and training days (T). Within each bar we show the percentage of each behavior recorded inside the firing fan relative to outside of the firing fan. Behavior codes are either a behavior or a combination of a behavior and a height code (1: 0-10 m, 2: 10-30 m, 3: >30 m) and are defined as follows: FL- flapping flight, GL- gliding flight, KT- kiting, SO- soar, DV- dive, HO- hover, PE- perch, AT-attack, PR-preen, MA- intraspecific maneuver, ME- interspecific maneuver, MI- individual maneuver, AT- attack, CP- carry prey.

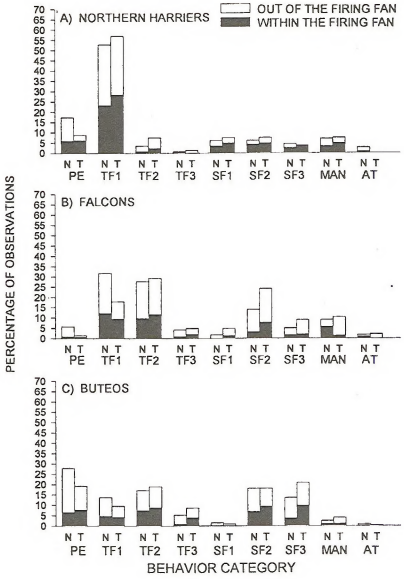


Fig. 32. Condensed repertoire of behaviors recorded for falcons utilizing the military firing ranges in 1994. Behavior codes are either a behavior or a combination of a behavior and a height code (1: 0-10 m, 2: 10-30 m, 3: >30 m) and are defined by combining codes in Fig. 31 as follows: TF = FL, GL; SF = SO, KT, HO; MAN = DV that were not associated with an attack MA, ME, MI; AT = DV associated with an attack; PE = PE, PR.

not change with respect to location (3-way interaction between location, behavior, and year: $G^2_{(24)} = 20.86$, $P = 0.66$).

Northern harrier behavior did not depend on either location or firing in 1994. We observed harriers travelling low or perching most often (Fig. 32A). We observed them most often in the firing fan, but their behaviors did not vary with respect to location. However, harriers did behave differently depending upon their location with respect to the firing fan among years (3-way interaction among location, behavior and year: $G^2_{(24)} = 46.67$, $P < 0.005$); but the change was not in response to military activity ($G^2_{(24)} = 5.71$, $P = 0.72$).

Buteo behavior also differed in response to military training (Fig. 32C; 2-way interaction between firing activity and behavior: $G^2_{(8)} = 20.4$, $P < 0.01$). They perched and travelled close to the ground more often on non-training days than on training days, and travelled high and soared more often on training than non-training days. Buteos tended to respond to training activities in and out of the firing fan differently among years (4-way interaction among firing activity, location, behavior, and year: $G^2_{(24)} = 34.26$, $P = 0.08$). Like falcons, buteos varied their behavior depending on firing in each year (3-way interaction among firing activity, behavior, and year: $G^2_{(24)} = 77.79$, $P < 0.005$), but use of behaviors also changed with respect to location (3-way interaction among location, behavior, and year: $G^2_{(24)} = 47.72$, $P < 0.005$).

The occurrence and fate of prey capture attempts by all raptors did not depend upon military training activities. In 1994, we observed 24 attempts to capture prey by raptors on training ranges; 6 (25.0%) were successful, 13 (54.2%) were unsuccessful, and the fates of 5 (20.8%) were not determined. Attempts occurred on training versus non-training days and in versus out of the firing fan with similar frequency in 1994 ($X^2_{(1)} = 0.296$, $P = 0.59$), and in the combined sample of 274 attacks from 1991-94 ($X^2_{(1)} = 0.538$, $P = 0.46$). Furthermore, success rate did not differ with respect to military training or location of the attempt relative to the firing fan (3-way contingency table comparing success versus failure, in versus out of the fan, and on hot versus cold days: $X^2 = 0.019$, $P = 0.89$ [1994]; $X^2 = 2.05$, $P = 0.15$ [1991-1994]). The average hourly attack rate was lower on ranges with military firing than on ranges that were not firing. Attacks per hour averaged 0.20 ($n = 16$ ranges, SD = 0.16) on non-firing days, but only 0.10 ($n = 16$ ranges, SD = 0.10) on firing days ($F_{(1,15)} = 9.30$, $P = 0.008$). The ratio of successful to unsuccessful attempts did not differ on firing versus non-firing days during the 4 years of the study (2-way interaction between success and firing: multivariate $F_{(3,13)} = 0.58$, $P = 0.64$).

Golden Eagles.--We captured 23 golden eagles during 43 trapping days, often with 2 crews out per day. We spent 3 days trapping at the PP&L 119 territory and captured the target adult female, replacing her malfunctioning transmitter with another backpack transmitter (which also failed). We spent an additional 6 days trapping in the PP&L 119 territory and captured a subadult male that had been seen consistently with the resident female and had copulated with her. This male was instrumented with a tail-mount transmitter. He remained in the territory for ≥3 weeks before he disappeared and was replaced by an adult male. We do not know if the adult male forced the subadult from the territory, or if the subadult left on his own. We spent 10 days trapping at the Cabin territory trying to re-instrument the female that had a malfunctioning transmitter, or to instrument the adult male. We captured 4 non-target eagles during this period, and captured and placed a tail-mounted transmitter on the adult male. This male had distinctive white "epaulets" which have also been present on ≥2 of his offspring and on a third subadult captured in the OTA. We also trapped in the OTA and captured 15 golden eagles, 6 of which (4 adults and 2 subadults) received both a satellite (backpack) and a conventional (tail-mounted) transmitter. One adult eagle had been instrumented in 1993 with a satellite transmitter; we replaced the old satellite transmitter with a new one.

Of the 7 territories at which we observed behavior of instrumented eagles, only 2 transmitters maintained consistent output (Beercase and Ogden). The remaining transmitters functioned, but with a severe decrease in range, or only when the solar panel was in full sun. We found solar panels to be of little use, as transmitters functioned intermittently, even on days with full sun. This lack of fully functioning transmitters limited our ability

to maintain visual contact with the eagles, and caused us to reduce tracking effort at 2 territories where non-breeding status (PP&L 119) and a failed nesting attempt (Wildhorse) made the pairs difficult to locate.

Influence of Telemetry Packages.--Radio-tagged golden eagles had significantly different reproductive success than unmarked eagles among the 3 years of study (3-way interaction among treatment, year, and success rate: $G^2_{(2)} = 5.82$, $P = 0.054$). Radio-tagged eagles had success rates similar to those of unmarked eagles in 1992, much lower reproductive success than unmarked eagles in 1993, and slightly higher reproductive success than unmarked eagles in 1994 (Fig. 33).

The number of young fledged differed significantly among years and between radio-marked and control eagles ($F_{(2,21)} = 4.18$, $P = 0.03$). The number of young produced by radio-marked eagles was much lower than the number produced by control eagles in 1993, yet was the same or slightly higher during 1992 and 1994 (Fig. 33).

The number of young fledged per successful nest did not differ significantly between radio-marked and control eagles among years ($F_{(2,33)} = 1.67$, $P = 0.21$). There was a tendency for eagle productivity to be sensitive to yearly variation ($F_{(2,33)} = 2.40$, $P = 0.11$). The number of young fledged in 1993 was lower than the numbers fledged in 1992 and 1994. Although there was no difference between radio-marked and control eagles in number fledged per successful nest when we pooled all years ($F_{(1,33)} = 0.57$, $P = 0.45$), the number of young produced by successful radio-marked eagles was lower than that produced by control eagles in 1993.

Spatial Use Patterns of Territorial Eagles.--Home ranges of eagles again centered on the nest, and sizes and shapes of territories in 1994 closely mirrored home ranges observed in 1993 for most individuals (Figs. 34-36; Tables 13, 14). Ninety-five percent harmonic mean home range size varied from 45 ha to 21,629 ha in 1994. There was no significant change in home range size from 1993 to 1994 for well-sampled birds. The Wildhorse range and the PPL 119 range decreased by the largest amount, but this was probably due to the decreased tracking effort at these sites. There was no evidence of the bimodal use area that was evident in previous years in the PPL 119 territory. Black Butte was the smallest home range again in 1994 (Tables 13, 14). Core use areas for all territories where we conducted multiple years of observation remained constant for individuals, although all pairs used new nests. Overlap of 1994 ranges on 1993 ranges (Figs. 34-36) was 93.3% ($n = 9$, SD = 9.4%). Overlap of 1994 ranges on 1992 ranges was 89.1% ($n = 7$, SD = 14.4%). The 2 territories where we reduced observations were much smaller than the 1993 ranges (Wildhorse: 8.6% of 1993 range; PPL 119: 35.0% of 1993 range).

Male ($n = 6$) and female ($n = 4$) eagles did not show consistent differences in travel distances (Tables 13, 14; Fig. 37). Travel distances to unique daily locations from the nest for males in 1994 averaged 1,715 m (SD = 1,483), whereas females averaged 1,738 m (SD = 1,432). Over the 4 years of study, male travel distance averaged 2,208 m (SD = 2,787), and female travel distance averaged 2,660 m (SD = 5515: $F_{(1,365)} = 0.08$, $P = 0.78$). As in previous years, male and female eagles did not differ in home range size in 1994 (Tables 13, 14; $F_{(1,9)} = 0.33$, $P = 0.58$). The 95% harmonic mean home ranges averaged 3,973 ha (SD = 4,906) for males and 2,478 ha (SD = 1,808) for females.

We located eagles closer to the nest during the breeding season than after the nest had failed or young had fledged (Fig. 38; $F_{(1,4)} = 9.12$, $P = 0.39$). There was no significant difference in travel distance among years ($F_{(2,8)} = 0.05$, $P = 0.89$), or among year and breeding season ($F_{(2,8)} = 0.50$, $P = 0.53$). We pooled data across years and found that eagles from different territories had significant differences in travel distances during breeding and non-breeding seasons (interaction of season and territory: $F_{(1,7)} = 2.29$, $P = 0.027$).

Use of OTA. -- As in previous years, use of the OTA by territorial golden eagles was low. Only 2 of the territorial eagles used the OTA in 1994; the Cabin pair of eagles ranged into the southwestern portion of the OTA to favored winter perches (Fig. 35). Occasionally, we observed territorial golden eagles perched and/or roosting on the powerline poles that mark the southern boundary of the OTA.

Table 13. Home range characteristics of paired golden eagles determined from radiotelemetry, 1993-94.

Nesting[a] Area	Sex	Burn	N	Mean distance from:[b] Nest	Hc	Ac	Hc-Nest	Max distance from:[b] Nest	Hc	Ac	Harmonic Mean Home Range[c] Max	95%	90%	50%	Harmonic Mean Home Range Shape[d] Hr	D	Sk	K	Sp
Brcs	M	Y	133	2,554	83	1,937	1,138	11,010	10,170	9,169	21,629	4,393	3,661	520	84	7.3	98.3	45.8	526
BlkBt	M	Y	133	811	88	824	175	2,714	2,620	2,464	1,479	767	506	78	89	7.7	34.2	34.7	400
Cabin	F	Y	19	3,554	353	3,537	7,395	7,419	8,508	5,126	929	548	445	252	373	3.3	45.1	10.6	1,209
Cabin	M	Y	27	2,699	512	2, 939	7,395	7,419	9,421	6,216	1,691	1,669	1,207	260	533	4.0	46.5	8.5	1,129
GVSC	M	N	25	4,896	415	5,667	243	24,270	22,090	21,750	17,554	14,398	6,378	752	433	4.2	3.3	11.0	1,225
WildH	F	N	18	3,781	16	2,646	3,629	19,020	15,440	15,920	12,856	2,997	1,700	481	18	4.1	113.4	32.8	143
WildH	M	N	24	3,284	596	2,171	2,360	19,020	17,650	16,460	17,637	4,805	1,403	345	622	2.4	5.4	4.4	1,139
Beech	M	Y	165	969	62	890	416	4,776	4,944	4,807	5,185	1,258	704	103	62	6.8	41.5	41.5	380
PL119	F	N	39	1,299	8	1,186	3	4,762	4,761	4,996	4,156	1,632	1,021	172	19	4.1	150.8	36.9	168
PL119	M	N	9	1,673	729	1,668	1,075	5,256	4,996	4,384	521	521	175	84	820	1.0	1.1	1.7	1,325
Ogden	M	N	127	2,931	109	2,694	5,511	7,171	9,713	6,791	11,232	4,376	2,933	784	110	9.6	339.1	73.9	833

[a] Nesting areas are abbreviated as follows: Brcs = Beercase, BlkBt = Black Butte, GVSC = Grand View Sand Cliff, WildH = Wild Horse, Beech = Beecham, PL119 = PP&L 119.
[b] Distance expressed in m, abbreviated as follows: Hc - harmonic center, Ac - arithmetic activity center.
[c] Home ranges expressed in ha.
[d] Hr - sum of the reciprocal distance (d^{-1}) to each fix, divided by the number (n) of distances and then re-inverted (i.e., $n/\Sigma d^{-1}$), D - dispersion, Sk - skewness, K - kurtosis, Sp - spread.

Table 14. Home range characteristics of paired golden eagles determined from radiotelemetry, 1993-94.

Nesting[a] Area	Sex[b]	Burn	N	Convex Polygon Home Range Max[c]	90%	70%	50%	Maximum Polygon width(m)
Brcs	M	Y	133	6852	2745	1185	218	15220
BlkBt	M	Y	133	722	367	235	133	3861
Cabin	F	Y	19	2211	1960	1559	1313	8533
Cabin	M	Y	27	3076	2801	2467	2384	9444
GVSC	M	N	25	271	47	21	20	29110
WildH	F	N	18	2925	916	426	237	18870
WildH	M	N	24	5727	705	295	154	18870
Beech	M	Y	165	1857	442	158	64	6839
PL119	F	N	39	1346	964	282	102	9139
PL119	M	N	9	753	188	107	17	5755
Ogden	M	N	127	5599	3623	3297	2650	12020

[a] Nesting areas are abbreviated as follows: Brcs = Beercase, BlkBt = Black Butte, GVSC = Grand View Sand Cliff, WildH = Wildhorse, Beech = Beecham, PL119 = PP&L 119.
[b] M = Male; F = Female; B = Both
[c] Home ranges expressed in ha.

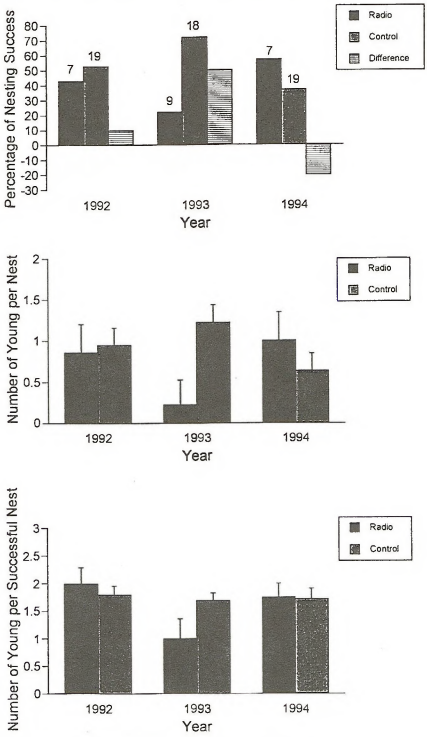


Fig. 33. Measures of productivity compared between radio-tagged and control golden eagles for 1992-94 breeding seasons. Difference in panel 1 equals productivity by control eagles minus productivity by radio-tagged eagles. Numbers in panel 1 are sample sizes for each panel.

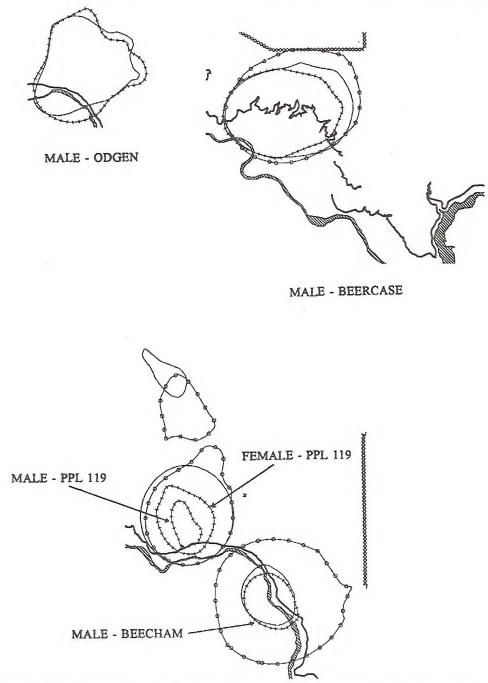


Fig. 34. Home ranges for adult golden eagles throughout the 1991-94 seasons. The 95% harmonic mean ranges are plotted for the male and female from PPL 119 (bimodal range in 1991-1993) and the male from Beecham in the lower portion of the figure, for the male from Ogden in the upper left portion, and the male from Beercase in the upper left portion. Lines with circles indicate 95% harmonic mean home ranges for 1991-92, solid lines indicate the 1992-93 home range, and lines with hatch marks indicate the 1993-94 range. The Snake River (hatched area), canyon rim (thick solid line along river), and the OTA boundary (connected squares) are included for orientation. All ranges are drawn to the same scale (1:312,500) and oriented with north at the top of the page unless otherwise noted.

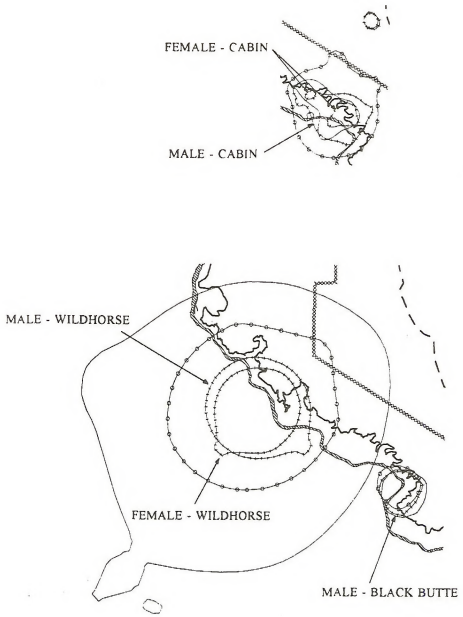
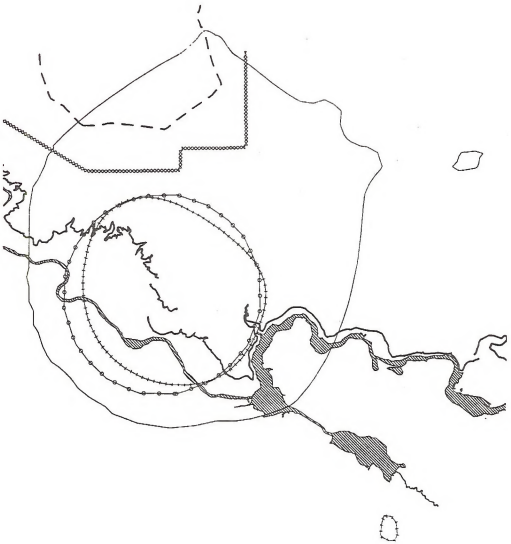


Fig. 35. Home ranges for adult golden eagles throughout the 1991-94 seasons. The 95% harmonic mean ranges are plotted for the male and female from Wildhorse and the male from Black Butte in the lower portion of the figure and for the male and female from Cabin in the upper portion. Landmarks and lines are represented as in Fig. 34 with the addition of the Range Road (alternating solid and open line). All ranges are drawn to the same scale (1:312,500) and oriented with north at the top of the page unless otherwise noted.



MALE - GRAND VIEW SAND CLIFF

Fig. 36. Home ranges for adult golden eagles throughout the 1991-94 seasons. The 95% harmonic mean ranges are plotted for the male from Grand View Sand Cliff. Landmarks and lines are as represented in Figs. 34 and 35. All ranges are drawn to the same scale (1:312,500) and oriented with north at the top of the page unless otherwise noted.

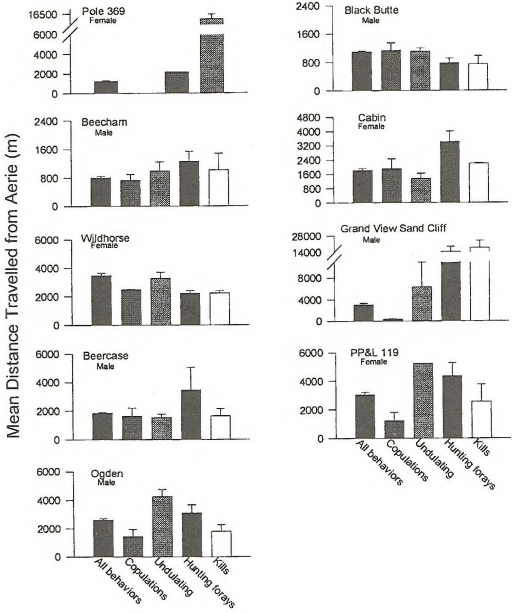


Fig. 37. Travel distances of adult golden eagles to locations where copulations, undulating flights, attacks and kills were observed. Average travel distance to all locations is plotted first for each bird. Sample sizes are given above each mean + 1 SE.

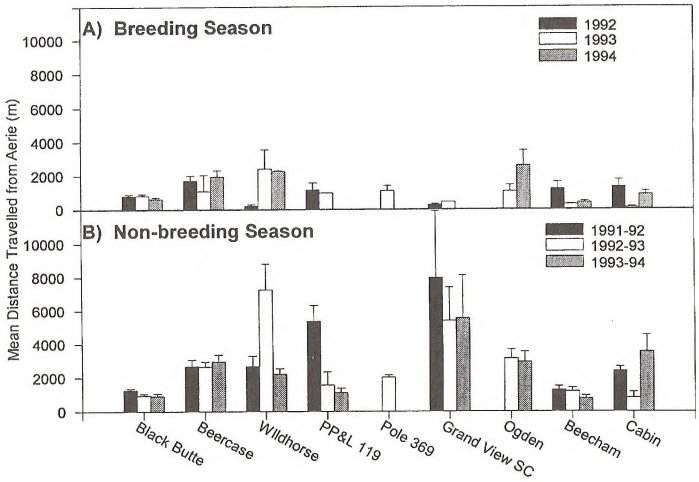


Fig. 38. Travel distances of adult golden eagles during the breeding season (A) and during the non-breeding season (B) in 1991-94. Means + 1 SE are plotted.

Foraging Behavior.--We observed 31 hunting forays and 13 successful forays during 104 observation days in 1994. We witnessed fewer forays than in previous years, even though we spent more observation days in the field (104 days vs. 94 days in 1993). This decrease in number of forays observed was probably due to a reduced amount of time that we had instrumented eagles in view. Instrumented eagles were in view for 227 hrs in 1994, which represents a 32% decline from 1993 and a 48% decline from 1992. This, in turn, is probably due to malfunctioning batteries in all but 2 eagle transmitters.

A summary of golden eagle forays is included in Table 15. Although we suspect many hunting forays were missed, we saw no black-tailed jackrabbit (*Lepus californicus*) kills. In 1993 and 1994, jackrabbits comprised >29% of the kills observed. Rock doves (*Columba livia*) were the most common prey item observed, followed by Townsend's ground squirrels (4 rock doves = 30.8% and 3 squirrels = 23.1%). Ground squirrels have been the primary or secondary prey item observed each year. As in previous years, we observed most forays and kills in the canyon in low-disturbance shrubland (Fig. 39).

Table 15. Golden eagle foraging summary for 1994. Habitat codes (Watts and Knick, this volume) were used for field classification of habitat type. Numbers in parentheses refer to the number of that prey type that was chased or taken by hunting golden eagles.

			Hunting Attempt		Hunting Success	
Territory	Sex	Habitat (code)	#Forays	Prey type chased (#)[a]	#Kills	Prey type taken(#)[a]
Beecham	M	Cliff	8	Pigeon (7) Unknown (1)	3	Pigeon (2)
		Cheatgrass	1	TGS (1)		
Beercase	M	Rabbitbrush (IA8)	1	Cottontail (1)	1	Cottontail (1)
		Russian Thistle (ID4)	1	Unknown (1)	0	
		Unknown	3	Unknown (3)	0	
Black Butte	M	Cliff	1	Pigeon (1)	0	
		Talus	2	Snake (1)	1	Snake (1)
		Greasewood (IA4)	1	TGS (1)	1	TGS (1)
		Unknown	1	Mallard duck (1)	1	Mallard duck (1)
Cabin	F/M	Shadscale (IB2)	1	Unknown (1)	0	
		Greasewood (IB4)	1	Unknown (1)	0	
		Cheatgrass (IIB2)	1	Chukar (1)	0	
		Unknown	1	Unknown (1)	0	
Grand View Sand Cliff	M	Talus	1	Snake (1)	1	Snake (1)
Ogden	M	Cliff	1	Pigeon (1)	1	Pigeon (1)
		Talus	2	Pigeon (1) Unknown (1)	2	Pigeon (1) Unknown (1)
		Sagebrush(IA1)	3	Unknown (3)	0	
		Winterfat(IA3)	1	TGS (1)	1	TGS (1)
		Kleptoparasitized a Northern Harrier	1	Mammal (1)	1	Mammal (1)
PP&L 119	F	No hunting attempts observed				
Wildhorse	M	No hunting attempts observed				

[a] Prey types abbreviated as followed: TGS=Townsend's ground squirrel

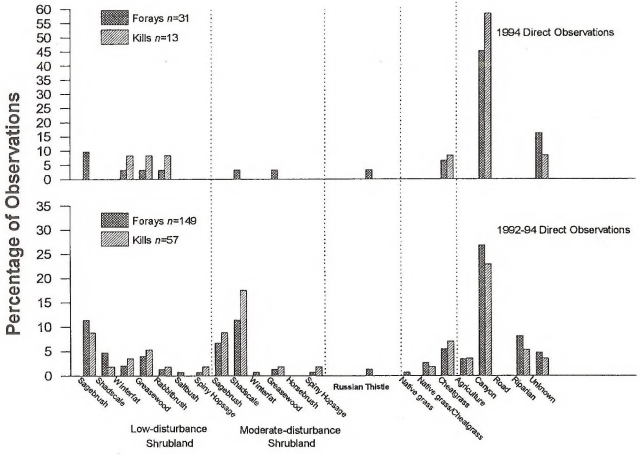


Fig. 39. Habitat types where breeding golden eagles were observed hunting (Forays) and capturing (Kills) prey in 1993 and for 1992-93 combined, and habitat available and used derived from satellite imagery within the territorial areas north of the river. Low and moderate disturbance shrubland and other habitat types are as defined by Knick (this volume).

Spatial Use Patterns of Eagles Wintering in the OTA.--From 4 January to 3 March 1994 we attempted to locate the non-canyon nesting golden eagles wintering in the OTA. During 37 observation days ($\bar{x}$ per individual = 10.6 days, n = 5, SD = 6.2 days), we successfully obtained a signal or a visual location on an instrumented individual each day. As in 1993, adults tended to be found in the OTA a higher percentage of the time than did subadults. We obtained visual or audible contact with adults an average of 61.3% (n = 4 eagles, SD = 12.0%) of the days that we attempted to find them. The adult female we captured in both 1993 and 1994 used the same area in both years (100% overlap of 1993 range with 1994 observed range) and was the individual that was most often located during observations (73.3% of attempts). We made visual or audible contact with subadult eagles during only 36.1% (n = 2 eagles, SD = 2.5%) of our attempts, primarily because they made frequent excursions out of the NCA. We obtained an average of 72.8 (n = 4, SD = 21.7) unique (not repeated within a day) locations per adult bird and 32.5 (n = 2, SD = 24.7) unique locations per subadult during these observations. The satellite provided an average of 215 (n = 3, SD = 79.5) unique locations per adult bird and 396.5 (n = 4, SD = 26.2) unique locations per subadult during this time. One satellite transmitter on an adult malfunctioned soon after it was applied, and very few (n = 20) locations were obtained, so we have omitted these data from analyses.

As in 1993, the size of use areas defined by satellite fixes for each individual depended upon the quality (LQ code; U. S. Fish and Wildl. Serv. 1990) of the location estimates included. Mean use areas defined by direct observation were smaller than those defined by satellite locations in all cases in 1994 (all satellite locations: $\bar{x}$ difference = -2,731.1 km, n = 5, SD = 788.4 km; LQ 1 - LQ 3: $\bar{x}$ difference = -398.3 km, n = 5, SD = 304.6 km; LQ 2 - LQ 3: $\bar{x}$ difference = -110.5 km, n = 5, SD = 168.4 km), but small sample sizes preclude any assessment of significance. We saw this same trend when we combined data from 1993-94 (all satellite locations: $\bar{x}$ difference = -7,582.6 km, n = 9, SD = 7,738.5 km; LQ 1 - LQ 3: $\bar{x}$ difference = -35,648.5 km, n = 5, SD = 101,733.0 km; LQ 2 - LQ 3: $\bar{x}$ difference = -61.7 km, n = 9, SD = 132.4 km), but only the difference between observed locations and all satellite locations was significant (t = -2.94, 8 df, P = 0.02).

Use areas of adult golden eagles (n = 3; observed locations: $\bar{x}$ = 10,154.6 km, SD = 7,035.5; all satellite locations: $\bar{x}$ = 2,674.3 km, SD = 1,052,121.1 km; LQ 1 - LQ 3: $\bar{x}$ = 280.5 km, SD = 308.0 km; LQ 2 - LQ 3: $\bar{x}$ = 142.6 km, SD = 180.7 km) that wintered in the OTA were smaller than those of subadult eagles (n = 2; observed locations: $\bar{x}$ = 153.9 km, SD = 175.6 km; all satellite locations: $\bar{x}$ = 2,985.4 km, SD = 634.7 km; LQ 1 - LQ 3: $\bar{x}$ = 744.1 km, SD = 56.2 km; LQ 2 - LQ 3: $\bar{x}$ = 231.4 km, SD = 27.3 km) in 1994. Combining 1993-94 data yielded similar results: adult ranges (n = 6; observed locations: $\bar{x}$ = 8.5 km, SD = 5.2 km; all satellite locations: $\bar{x}$ = 6,528.1 km, SD = 5,909.3 km; LQ 1 - LQ 3: $\bar{x}$ = 2,157.6 km, SD = 4,548.6 km; LQ 2 - LQ 3: $\bar{x}$ = 74.5 km, SD = 136.5 km) were generally smaller than subadult ranges (n = 3; observed locations: $\bar{x}$ = 111.1, SD = 144.7; all satellite locations: $\bar{x}$ = 8,971.6 km, SD = 9,819.3 km; LQ 1 - LQ 3: $\bar{x}$ = 77,355.1 km, SD =152,955.0 km; LQ 2 - LQ 3: $\bar{x}$ = 285.9 km, SD = 261.6 km), but not significantly smaller (observed locations: t = 1.872, 8 df, P = 0.10; all satellite locations: t = 0.497, 8 df, P = 0.63; LQ 1 - LQ 3: t = 1.243, 8 df, P = 0.25; LQ 2 - LQ 3: t = 1.696, 8 df, P = 0.13).

The average departure date for adults migrating north was 14 March (n = 3 adult eagles, SD = 6 days). The adult that departed earliest (9 March) travelled to central Alaska, arriving in late March. Of the other migratory adults, 1 departed on 12 March and travelled to southeastern Alaska, and the other departed on 20 March and travelled to British Columbia; both arrived in early April. The non-migratory adult remained in southwestern Idaho during the breeding season and was found injured (shot) in his winter use area on 20 September 1994. Because the subadult eagles that we captured in the OTA showed little affinity to any particular area within the OTA, we could not assign a departure date. Both subadults made frequent excursions to the south and east during the winter and remained in the area until their transmitters stopped transmitting in mid-late March.

DISCUSSION

Influence of Radio Transmitters

Capture and instrumentation of eagles and falcons in 1994 did not influence their productivity. This suggests that, contrary to our observations in 1993, low prey populations do not accentuate any negative effects of radio-tagging because prey populations were again low in 1994 (Van Horne, this volume, Watts and Knick, this volume). Golden eagles appeared to suffer a more detrimental effect of radio-tagging than did prairie falcons, especially in 1993. Current analyses suggest that poor productivity of golden eagles in 1993 may have been a result of radio-tagged birds nesting in exposed locations more frequently than noninstrumented eagles.

Ranging Habits of Prairie Falcons

Prairie falcons ranged over large areas and exhibited even diet compositions in 1994. These responses are consistent with reactions to low numbers of their primary prey (Townsend's ground squirrels) previously reported (U.S. Dep. Inter. 1979, Marzluff et al. 1993). However, in contrast to falcons nesting in previous years of low prey abundance, falcons in 1994 were able to maintain a high level of productivity. Infestations of nest ectoparasites were lower in 1994 than 1993 (McFadzen, pers. obs.), suggesting that this factor may account for a substantial amount of the variation in productivity. In addition, 1994 supported the smallest population of nesting falcons observed in the NCA (Lehman et al., this volume). The few falcons that returned to nest in 1994 therefore may have obtained the most productive territories and faced lower competition for food than those nesting during previous prey crashes.

Prairie falcons that nested in the OTA shadow continued to range farther, use a more even distribution of food items, and cache food less frequently than birds nesting west of the shadow. This behavioral flexibility allowed falcons in the OTA to be as productive as those nesting west of the OTA. The ability of OTA shadow falcons to compensate for low prey levels in 1994, unlike in 1993 when prey was low and ectoparasites were high, further suggests that ectoparasites play an important role in determining falcon productivity.

Effects of Military Training on Raptors Utilizing Firing Ranges

The influence of military training on raptors observed on firing ranges was lower in 1994 than in previous years (Fig. 29). This is likely because few raptors were observed on the ranges in 1994. The raptor community on the ranges also changed in 1994 (Fig. 28); burrowing owls (*Speotyto cunicularia*) were more abundant, and northern harriers were less abundant than in previous years. Raptors observed on the ranges in 1994 may therefore be less vulnerable to military activity because they nest in concealed locations (burrowing owls) or off the ranges entirely (buteos and eagles).

Ranging Habits of Golden Eagles

Despite increased efforts to re-trap and follow eagles in 1994, some territories remained difficult to observe because of radio failure. Two problems are worth noting: (1) the power lines in the study area, which are used extensively by eagles, can destroy transmitters, and (2) solar panels used to lengthen the lifespan of transmitters are ineffective on eagles because eagles preen the transmitters into their feathers, thus covering the panels.

Ranging habits of eagles remained consistent across the years of our study. Eagles used the same areas each year despite changing prey abundances and shifting nest sites (Figs. 34-36). Use areas expanded greatly from the breeding to the nonbreeding season, but the degree of expansion was highly individualistic (Fig. 38). This is likely due to differences in habitat, prey abundance, and individual experience among territorial birds.

The OTA continued to be used infrequently by eagles breeding in the canyon (Figs. 34-36), but served as an important wintering area for adults that breed in northern Canada and Alaska. Subadults also used the OTA during the winter, but they were more nomadic than the migratory adults. Migratory adults resided in consistently occupied winter ranges in the OTA and appeared to return to these ranges in subsequent years. Interestingly, they did not defend these winter ranges.

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Appendix A. Band combinations and physical characteristics of adult prairie falcons captured in the SRBOPNCA, 1994.

Date	Territory	Band No.[a]	Color Band color[b]	leg	code	Sex	Mass (g)	%Crop	Wing (mm) span	chord	Toe Pad (mm)	Radio Freq.	Time Held (min)	No. Fledged
06 MAR	PFI	*1807-47705	GR	L	6/6	F	1000	0-25	1120	350	88.5	164.085	81	6
07 MAR	GEOICATION SITE UPSTREAM	2206-22900	RD	R	3/U	M	495	0-25	960	314	78.6	164.164	95	0
07 MAR	UNKNOWN	*987-35886	BK	L	A/A	F	880	0-25	1094	355	92.0	e.e	15	e
08 MAR	CORRAL	2206-26701	RO	R	4/P	M	595	26-50	958	306	77.5	164.465	78	5
08 MAR	CORRAL	1807-41448	RD	R	E/S	F	1035	0-25	1120	354	90.5	e.e	28	5
14 MAR	ROSIE I RED-TAIL	*0816-74712	BK	L	O/B	M	525	0-25	948	304	77.3	164.404	82	5
14 MAR	UNKNOWN	2206-22899	RD	R	O/B	M	540	0-25	924	306	79.1	e.e	45	e
16 MAR	SWAN OAM ROAD SOUTH SIDE	1807-41450	RO	R	A/B	F	995	26-50	1100	356	89.5	164.486	90	4
16 MAR	FANG	2206-26711	RO	R	4/Z	M	540	0-25	906	305	76.6	164.315	66	0
16 MAR	SWAN OAM ORAW	1807-41449	RO	R	A/A	F	930	0-25	1086	342	89.6	164.015	57	4
17 MAR	CONNING TOWER OOWNSTREAM	2206-26702	RD	R	3/W	M	581	0-25	970	311	79.0	164.296	49	≥2
17 MAR	BLACK BUTTE	1807-41459	RO	R	A/O	F	990	26-50	1130	356	89.6	164.376	40	3
17 MAR	OGDEN ROCK UPSTREAM	*1807-01280	BK	L	F/9	F	818	e	1100	349	86.0	164.355	49	0
18 MAR	POWERLINE	1807-41460	RD	R	A/E	F	905	0-25	1084	342	89.0	164.216	89	0
20 MAR	MASSACRE FACE	*1807-01396	BK	L	B/V	F	945	0-25	1100	350	88.0	164.044	62	0
20 MAR	SAN SEBASTIAN CAVERN	1807-41461	RO	R	A/G	F	905	0-25	1100	354	89.7	164.395	75	0
21 MAR	PEREGRINE CLIFF	1807-41462	RD	R	A/H	F	820	0-25	1100	342	91.6	164.186	60	4
22 MAR	FEVER BASIN	1807-41463	RD	R	A/K	F	831	0-25	1106	344	89.0	164.264	70	0
22 MAR	CORRAL DOWNSTREAM	*2206-22898	BL	L	A/P	M	658	0-25	940	315	81.4	164.135	46	0
23 MAR	SWAN I DRAW UPSTREAM	2206-26712	RO	R	O/A	M	540	0-25	960	305	75.0	164.105	80	5
23 MAR	FEVER BASIN POINT OS	2206-26713	RO	R	O/C	M	606	26-50	950	300	75.8	164.126	68	2
23 MAR	FALCON FLATS CAVE EAST	1807-41452	RD	R	E/V	F	e	e	e	e	e	e.e	08	e
25 MAR	HALVERSON TRAIL	2206-26703	RO	R	E/T	M	556	0-25	946	307	78.1	164.456	59	≥3
25 MAR	SLICE DRAW	2206-26704	RO	R	4/U	M	661	26-50	990	299	75.3	164.496[d]	46	e
28 MAR	NO BIRO ROCK	2206-26714	RO	R	O/O	M	630	0-25	954	306	75.6	164.155	75	0
30 MAR	SWAN OAM THREE POLES	1807-41464	RO	R	A/M	F	1065	0-25	1120	343	90.1	164.024	60	6
31 MAR	SWAN I DRAW UPSTREAM	1807-41465	RD	R	A/N	F	1025	0-25	1100	347	92.5	164.055	60	5
01 APR	COLT DOWNSTREAM	2206-26715	RD	R	O/E	M	585	0-25	982	316	77.2	164.076	69	4
04 APR	FERRY	1807-41451	RO	R	E/U	F	930	0-25	1090	345	86.6	164.336	57	0
05 APR	HELL HOLE PEREGRINE	2206-26716	RD	R	O/G	M	560	0-25	980	303	77.0	164.246	74	5
05 APR	UNKNOWN	2206-26717	RO	R	O/K	M	535	0-25	952	297	77.0	164.425	70	e
05 APR	UNKNOWN	*2206-22859	RO	L	3/H	M	590	26-50	954	297	78.8	e.e	20	e
14 APR	SAND ROCK	*2206-22895	BL	L	A/K	M	597	0-25	950	303	74.7	164.195[d]	72	3
14 APR	UNKNOWN	*816-74858	BK	R	4/6	M	565	e	e	e	e	e.e	15	e
15 APR	OGDEN ROCK	1807-41466	RO	R	A/R	F	970	26-50	e	341	90.5	164.096	90	≥1
15 APR	UNKNOWN	*816-74879	Bk	L	6/E	M	555	0-25	e	305	80.5	e.e	30	e
19 APR	BEERCASE UPSTREAM	2206-26718	RD	R	O/H	M	540	0-26	958	305	75.7	164.065	76	0
29 APR	CSJ	*816-74715	BK	L	O/E	M	570	0-25	936	299	75.3	164.223[d]	50	3
03 MAY	UNKNOWN	*1807-38543	RD	L	C/H	F	830	0-26	e	e	e	e.e	25	e
05 MAY	UNKNOWN	*2206-22868	RD	R	2/T	M	600	0-25	e	e	e	e.e	16	e
17 MAY	SAND ROCK	*1807-01203	BK	R	V/S	F	890	0-25	1118	354	88.8	e.e	12	3

[a] * denotes previously banded individuals.

[b] Color: RD - Red, BK - Black, BL - Blue, GR - Green

[c] Bird not instrumented due to gravid condition.

[d] Individual shed radio

[e] Previously radio-tagged individual.

Appendix B. Band combinations and physical characteristics of golden eagles banded in the SRBOPNCA from November 1993 - March 1994.[a]

Date	Trap site or nesting area	Band No.	Time Held (hr:min)	Sex	Age	Mass(g)	%Crop	Wing Span	Wing Chord	Bill Depth	Head Culmen	Head Length	Hallux	Footpad	Treatment B/P/T[c]	Treatment Freq.
12 Nov 93	PP&L 119	629-18147[b]	1:50	F	Ad	5,200	50	2,080	622	30.6	47.5	125.8	57.2	145.2	B	4.925
19 Nov 93	Cabin	629-26712	0:53	U	Subad	4,275	75-99	-	590	27.5	40.6	116.3	49.4	-	P	-
07 Dec 93	Cabin	629-26713	0:59	U	Subad	4,400	75-99	-	580	29.5	42.0	121.0	48.5	-	P	-
13 Dec 93	Cabin	629-26714	1:06	F	Subad	-	75-99	-	650	32.0	46.7	129.0	55.4	-	P	-
21 Dec 93	Tadpole	629-26715	1:25	U	Subad	4,800	0-25	2096	622	29.2	41.2	116.1	54.0	136.0	S	5.094
21 Dec 93	Tadpole	629-26716	0:56	M	Subad	4,275	0-25	2,064	594	27.5	40.5	119.4	50.8	133.3	S	5.015
10 Jan 94	Tadpole	629-26717	1:13	M	Subad	4,100	0-25	1,986	585	28.0	40.9	119.4	51.4	128.7	P	-
14 Jan 94	Little Joe Butte	629-26718	1:00	M	Subad	4,575	0-25	2,026	596	29.3	42.4	118.6	52.1	134.5	P	-
17 Jan 94	Little Joe Butte	629-18111[b]	0:45	M	Subad	3,800	0-25	2,044	593	27.8	42.4	120.7	49.3	132.4	-	-
17 Jan 94	Little Joe Butte	629-26719	1:30	M	Ad	3,900	0-25	2,088	610	28.2	43.7	-	49.8	135.4	S	5.055
19 Jan 94	Little Joe Butte	629-26720	1:15	M	Subad	4,150	75-99	-	580	27.6	38.5	119.6	48.5	131.3	P	-
27 Jan 94	Little Joe Butte	629-26721	1:50	M	Subad	3,950	0-25	1,966	579	27.4	40.3	119.5	50.5	128.9	P	-
27 Jan 94	Little Joe Butte	629-26722	1:00	M	Subad	3,775	0-25	2,008	595	27.4	42.3	117.1	47.7	122.4	P	-
27 Jan 94	Little Joe Butte	629-26704[b]	1:45	U	Ad	5,200	0-25	2020	641	30.4	45.4	127.4	60.3	138.0	S	5.074
28 Jan 94	Tadpole	629-26723	1:30	M	Subad	4,300	50-75	2010	605	30.0	42.9	118.0	52.5	133.2	P	-
28 Jan 94	Bigfoot	629-26724	0:50	M	Subad	3,800	0-25	1980	595	28.3	42.7	114.6	54.0	128.5	P	-
01 Feb 94	Little Joe Butte	629-26725	1:30	F	Subad	4,900	0-25	2010	615	31.2	47.9	125.0	57.5	147.6	P	-
08 Feb 94	Pleasant Valley	629-26726	2:30	M	Ad	3,650	50	1966	590	27.4	39.9	110.5	45.3	125.5	S	5.033
09 Feb 94	Cinder Cone	629-26727	2:15	M	Ad	4,100	0-25	1900	585	38.0	41.3	113.0	48.5	126.8	S	5.105
11 Mar 94	PP&L 119	629-26728	2:30	U[d]	Subad	4,075	0-25	-	614	27.5	41.7	118.5	50.3	139.7	T	4.925
22 Mar 94	Cabin	629-26729	0:51	F	Subad	4,500	0-25	-	610	29.3	44.2	121.0	-	142.5	-	-
31 Mar 94	Poen Road	629-26730	0:48	M	Ad	3,850	0-25	-	610	25.8	38.0	115.2	-	124.5	-	-
12 Apr 94	Cabin	629-26731	1:56	M	Ad	3,450	0-25	-	575	26.4	40.7	116.4	45.3	127.1	T	4.894

[a]All measurements expressed in millimeters

[b]Previously banded individual, measurements tend to indicate sex as female

[c]Treatment: B=backpack radio T=tailmount radio P=patagial tag S=tailmount radio and backpack satellite transmitter

[d]Measurements tend to indicate sex as female, but behavioral observations indicate sex as male

Raptor Distribution and Use of the Orchard Training Area (OTA) and Adjacent Areas, 1993-94

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ANNUAL SUMMARY

*We conducted 1,698 point counts of raptors and ravens in the Integration Study Area (ISA) between 16 July 1993 and 15 July 1994. Mean counts of raptors, common ravens (**Corvus corax**), northern harriers (**Circus cyaneus**), prairie falcons (**Falco mexicanus**), red-tailed hawks (**Buteo jamaicensis**), Swainson's hawks (**Buteo swainsoni**), ferruginous hawks (**Buteo regalis**), and rough-legged hawks (**Buteo lagopus**) in the 1993 dry, 1993-94 winter, and 1994 breeding seasons were the lowest recorded in their respective seasons since the beginning of the study in April 1991. We also recorded the fewest golden eagles (**Aquila chrysaetos**) in the 1993 dry and 1994 breeding seasons; however, more golden eagles were recorded in the 1993-94 winter season than have been recorded previously. Common ravens were recorded in significantly higher numbers outside the OTA in all 3 seasons. Red-tailed hawk counts were significantly higher outside the OTA in dry 1993 and breeding 1994. Ferruginous hawks were significantly more abundant inside the OTA than outside during the evening in the 1994 breeding season. We detected no significant differences in numbers among the 3 diurnal periods for any species in any season. The exclusion of sites within 2 km of active agriculture from the non-OTA data sets generally dropped the mean counts of each species, and all significant differences between inside and outside the OTA were lost. In addition, the diurnal use patterns for some species changed, indicating that birds were using sites closer to agriculture differently during the day than sites farther from agriculture.*

*We classified our sites as dominated by agriculture, sagebrush (**Artemisia tridentata**), shadscale (**Atriplex confertifolia**), grasses and exotic annuals, or shrub mosaic. The habitat association analyses confirm the unique utilization patterns of sites close to agriculture, especially in the dry and winter seasons. Ravens, northern harriers, red-tailed hawks, Swainson's hawks, and rough-legged hawks showed very strong associations with sites near agriculture in most seasons. Ravens also associated with sagebrush sites, as did northern harriers; however, harriers also avoided shadscale sites. Red-tailed hawks associated with agriculture only in the dry seasons and in the drought-stricken 1992 breeding season. This species showed no habitat associations during the winter seasons and avoided*

shadscale areas in the breeding seasons. Prairie falcons and golden eagles generally avoided agriculture, except during the worst of the drought. Prairie falcons also avoided grass sites. Golden eagles associated most strongly with sagebrush and shrub mosaic areas. Ferruginous hawks always avoided agricultural areas and associated most commonly with grass and shrub mosaic areas.

Using simultaneously observed paired sites, we could detect no influence of military activity on the presence/absence or mean number of raptors in the OTA in the 1993-94 non-breeding seasons or the 1994 breeding season. We could not detect a significant difference between the distribution of numbers of raptors recorded during no military activity and those recorded in association with bivouacs, vehicles, firing or aircraft in either the 1993 dry or 1994 breeding season.

OBJECTIVES

1. To compare raptor detection rates inside and outside the OTA during different seasons, different diurnal periods, and periods of military training and periods of no training.

2. To assess differences in habitat association by raptors and common ravens during different seasons, during different diurnal periods, and during periods of military training and periods of no training.

INTRODUCTION

Study 1 is part of a long-term investigation of the effects of military training on birds of prey and their prey populations in the Snake River Birds of Prey National Conservation Area (SRBOPNCA). Designed as an extensive survey of raptor distribution, behavior, and response to military activity, Study 1 is comprised of a series of point counts conducted during different temporal and military-related conditions.

The overall objective of this study is to provide information about the probability that a given tract of land in the SRBOPNCA will be used by a certain species of raptor under a given set of conditions (season, time of day, presence/absence of military activity). This information will allow managers to schedule military training for periods and locations that will have minimal impacts on birds of prey and allow them to prioritize areas for habitat protection and/or restoration. Although the immediate goal of the study is to assess the impact of military training on raptor distribution and behavior, the data collected herein will provide a base of information on the relative abundance of raptor species in the SRBOPNCA for use in long-term monitoring.

Study 1 is a year-round project with 3 field seasons per year: breeding (1 March - 15 July), dry (16 July - 31 October), and winter (1 November - 28/29 February). We have now completed all intended data collection and have 10 full seasons of observation (4 breeding, 3 dry, and 3 winter seasons). This report includes preliminary analysis of data collected in the 1993 dry, 1993-94 winter, and 1994 breeding seasons. We also included results and comments on the re-analysis of species-specific habitat associations for all previous seasons. This became necessary when we discovered, following rigorous field checking, that nearly 25% of our sites were misclassified on the GIS vegetation map.

METHODS

Raptor Detections

We used 189 point count sites throughout the Integration Study Area (ISA) north of the canyon rim: 70 sites were within the OTA, and 119 sites were outside the OTA. Site selection and pairing methods have been described in the project study plan (Watson and Strickler 1991), with modifications in the 1991 Annual Report (Strickler and Watson 1991). Each site was a circle of 1,000-m radius. Point counts were conducted in the same manner as in previous years, with each count consisting of a 20-min period of looking for all raptors and common ravens within 1,000-m of the center point. We alternated intensive scans of

90-degree quadrants of the horizon through 10 x 40 binoculars with 360-degree naked-eye scans. We observed every bird seen within 1,000 m for 60 sec and recorded the following data: species (if identifiable), time at which the bird was first seen, habitat over which the bird was flying, behavior over the 60-sec focal sample, and any appropriate comments. In addition, we collected the following data at each count: weather - temperature, wind speed, wind direction, and sky cover; number of cows; presence of prey and other predators, such as coyote, badger, etc.; and time and type of military activity.

Time of Day

We censused each site during each of 3 diurnal periods (morning, afternoon, and evening) during each season. The length of each diurnal period was a function of the length of photoperiod and consequently varied throughout the year.

Because of the lack of independence resulting from multiple counts at each site, our study design must be considered a repeated measures design, with diurnal period the main repeated factor. However, because of the nonnormal nature of our data, traditional repeated measures analyses of variance are not applicable. Permutation procedures, which are distribution-free and allow for repeated measures analysis, have been developed recently and shown to be a powerful, viable replacement for many standard parametric tests (Biondini et al. 1988; Slauson 1988; Cade and Hoffman 1990; Mielke 1991; B.S. Cade, N.E.R.C., NBS, pers. commun.). We used multi-response permutation procedures (MRPP; Slauson et al. 1991) throughout our tests of repeated measures models of raptor detection rates (Strickler and Watson 1993).

We ran separate analyses on dry 1993, winter 1993-94, and breeding 1994 counts. Sites with <3 counts in a single season were excluded from the analysis for that season. For the overall interaction between OTA (on = 1; off = 2) and diurnal period (morning = 1; afternoon = 2; evening = 3), we examined the multivariate tests in MRPP for interaction between the group effect (OTA) and trial effect (period) using linear contrast variables between the repeated measures (morning - [minus] afternoon; morning - evening; afternoon - evening). If we found no significant interaction, we ran univariate tests on the main group effect by averaging the repeated measures of each site into a single value and comparing the OTA and non-OTA data sets. We tested the main effect of diurnal period by a series of pairwise comparisons (morning vs. afternoon; morning vs. evening; afternoon vs. evening) that combined OTA and non-OTA data within periods (Looney and Stanley 1989). A significant interaction between OTA and period indicated that the time of day influenced the difference between numbers of birds detected inside and outside the OTA. We performed subsequent tests for subeffects of group and trial separately within levels of OTA and period. Each type of MRPP analysis involved a different number of tests to examine for OTA and diurnal differences. Because of the multiplicity of comparisons involved, Looney and Stanley (1989) and B.S. Cade (pers. commun.) recommend adjusting *P*-values with the Bonferroni approach. We adjusted tests for subeffects by dividing the critical *P*-values by the number of univariate tests (Harris 1985). The significance level for the general interaction analysis and the univariate tests was $P = 0.05$. The Bonferroni adjusted significance level for the pairwise period contrasts was $P = 0.017$. For the separate group and trial analyses, the adjusted significance level for the OTA/non-OTA comparisons within each period was $P = 0.017$. An adjusted significance level of $P = 0.008$ was appropriate for the simultaneous OTA and non-OTA period pairwise comparisons. We ran separate analyses on the 8 most abundant species: common raven, northern harrier, prairie falcon, red-tailed hawk, golden eagle, Swainson's hawk, ferruginous hawk, and rough-legged hawk.

Military Training

We gathered military activity data from a variety of sources. First, we recorded any training activity heard or seen while out in the field each day. We recorded the time of activity, and if possible the type and location of the activity. The limitations of such field observations are twofold: (1) actual type and location of training are difficult to assess, especially for artillery, which may be heard but not

seen; and (2) some types of training such as maneuvers and bivouacs could take place close to the count site without being heard or seen by the observer if, for example, the activity was on the opposite side of a butte or hill from the count site.

The Idaho Army National Guard (IDARNG) provided 3 additional sources of military activity data. The Range Management Input Worksheets provided general information on the daily activity of a particular military unit, including number of personnel, number and type of vehicles and aircraft, and amount and type of ammunition. These worksheets indicated that a certain number of people and equipment were present in a very general training area (usually 1 of 23 sectors into which the 53,015-ha OTA is divided) during a 24-hr period, but gave no specific time, duration, or location of actual movement or other activity. Second, we used the IDARNG Cinder Cone log book, a record of all communications with the range control center. The Cinder Cone log was primarily useful for determining when a range had been approved for firing. The "firing" designation, however, did not indicate whether or when firing actually occurred. Third, the digitally logged (GPS) locations of major military activity sites including bivouacs, assembly areas, showers, and communication points, in the OTA and the general dates they were in use. We entered the data into the BLM's Geographic Information System (GIS) to determine actual distance to each site. Unfortunately, although the UTM coordinates allowed us to determine location of military activity more precisely, "blanket" dates of activity, such as "May, June, July" did not reflect military presence on a time scale useful to us. The dates reflected generally heavy use of a site during the stated time period, but did not reflect actual use on a day by day basis. Sites were often empty as military units using the area changed. Where obvious discrepancies in military activity information were found, we used our local observations. The additional GPS-activity information increased our "military activity present" data set by 47% over what we had gathered during counts and from log books; however, we have strong reservations about the usefulness of these data without accurate dates on a shorter time scale. We again applied the "3 km - 3 hr" rule that we used in 1992 to training (Strickler and Watson 1992). If military activity of any sort occurred within 3 km and up to 3 hr before and while a count was being conducted at a site in the OTA, that count was considered to have taken place during a period of military training. Counts conducted when no known training took place within 3 km and 3 hr were said to have been in a period of no training. This classification of military activity, which we used in our analyses as a categorical variable, is clearly a broad definition that could result in a very conservative estimate of the influence of military activity. Until further information is available on the distance and time over which each of the various types of military activity effects carries, we must retain this generic approach.

Analyses of the effects of military training were greatly hampered by low sample sizes, so we could not run separate analyses on each species but lumped all birds of prey into a single variable, raptor. We tested the null hypothesis that military training does not influence use of the OTA by raptors in 3 ways. We compared raptor presence inside and outside the OTA during periods of military training and no training by simultaneously observing a subset of our sites, previously paired for similarity in habitat, distance from the canyon, and east or west of ISA midline (see Strickler and Watson 1991 for further details). Second, we compared the actual number of raptors recorded at OTA sites with and without military training, again using the paired count data. Third, we divided the military activity data set into specific types of military training and compared the distribution of raptor numbers recorded at OTA sites with a specific type of military training with the distribution at OTA sites without military activity.

Seasonal effects of military training have been noted in previous reports (Strickler and Watson 1993). We continued to investigate how seasonal timing of military training and the normal cyclical pattern in raptor abundance affect statistical results. When comparing non-simultaneous counts for effects of military activity, it was necessary to account for within season timing of observations (early - cycle 1; mid - cycle 2; late - cycle 3) (unpubl. data). Wherever appropriate and possible with our small data set, we ran analyses within cycles or matched the proportion of observations in each cycle in the data sets we were comparing. Only the simultaneously observed paired sites

directly controlled for the effects of seasonal timing, weather and habitat.

Repeated measures analysis was not possible for testing the influence of military activity on raptor detection rates inside and outside the OTA because the military activity label at each OTA site was not constant across all counts. Using only the paired counts, we formed contingency tables with presence or absence of both military activity and birds at OTA and non-OTA sites. We scored each pair of counts according to whether raptors were detected at the non-OTA member of the pair and not at the OTA site or raptors were seen at the OTA site but not at the non-OTA site. Because this type of scoring eliminated like pairs of counts (birds present at both sites or absent at both sites) our data set was considerably reduced. To avoid questionable results owing to sparse cells in the tables, we combined the dry and winter seasons into a single "non-breeding" group (these seasons tend to have fewer counts conducted during a "training" designation than do breeding seasons). We performed separate analyses on breeding and non-breeding seasons.

Additionally, we used univariate MRPP contrast analyses (similar to ANOVA) to compare actual numbers of raptors, rather than just presence/absence as in the contingency table analyses. To avoid problems of independence, we averaged the counts for each site whenever multiple records for a site were present in a particular data set. We created contrasts to compare counts between OTA military activity sites (PA=1) and their non-OTA pair (PA=2); OTA no military activity sites (PA=3) and their non-OTA paired sites (PA=4); OTA military activity sites (PA = 1) and OTA no military activity sites (PA = 3); and non-OTA sites with military activity on their OTA pair (PA = 2) and non-OTA sites with no military activity on their OTA pair (PA = 4). Points used in the within pair contrasts (1 vs. 2; 3 vs. 4) were observed simultaneously and automatically accounted for such factors as timing of observations, habitat, and weather conditions. Data in the within OTA (1 vs. 3) and within non-OTA (2 vs. 4) contrasts were not collected simultaneously and have no innate control of the above-mentioned factors. A significant result in the within-pair contrasts (1 vs. 2; 3 vs. 4) indicates that the mean number of raptors differed inside and outside the OTA during military training (1 vs. 2) and during no training (3 vs. 4). The results of contrasts 1 vs. 3 and 2 vs. 4 are not as easily interpreted. These contrasts are not between pairs and are subject to the complications of seasonal timing of military activity and raptor abundance. Sites observed early in the season have a much higher chance of counting a raptor than sites observed later in the season (Figs. 1, 2 Strickler & Watson 1993). Additionally, when military activity occurs later in the season (June, July), our military activity data set is biased toward the time of season when raptor numbers are low. Any comparison between OTA counts with no military activity (usually earlier in the season when raptor numbers are higher) and those observed during military activity (usually occurring later in the season when raptor numbers are declining) would be highly suspect; except that we have a control comparison in the non-OTA data set, the simultaneously observed pairs of those OTA sites. The 2 contrasts have the same distribution of cycle 1, cycle 2, and cycle 3 observations, and both analyses should be influenced equally by the potential timing problems. They also have the same distribution of habitat types and were observed under the same weather conditions. The main difference between the contrasts is the occurrence of military activity in the OTA set (1 vs. 3) and not in the non-OTA contrast (2 vs. 4). The important result in these contrasts is not whether they are significant or not, but whether the 2 contrasts have the same result: both significant or both non-significant. If the results from the contrasts are the same then it can not be said that military activity alone is influencing the raptor counts. If only military activity is significantly influencing the OTA counts, we would expect the contrast results to be different.

We also compared the distribution of numbers of raptors seen on OTA sites in the presence of various types of military training (bivouacs; wheeled or tracked vehicles; artillery, tank, or small arms firing; air traffic) to that seen at OTA sites where no military activity was recorded using contingency table analysis. We accounted for seasonal timing in these analyses by adjusting the no military activity data set to reflect the proportion of observations in each cycle as was observed under each specific type of military activity. This was done by selecting a subset of no military activity sites in a stratified

random manner from each cycle within each season. We did not run military activity analyses for the 1993-94 winter season because sample sizes were too small.

Habitat

Habitat Classification.-- During the site selection and pairing process (Strickler and Watson 1991), we described each point count site with ocular estimates of the percent cover of vegetation types (i.e., sagebrush, rabbitbrush (*Chrysothamnus* spp.), winterfat (*Ceratoides lanata*), shadscale, sage-dominated shrub mosaic, shadscale-dominated shrub mosaic, grass/exotic annual, and agriculture).

In 1993 we reported reanalysing all raptor/habitat associations using the "more precise estimate of habitat composition available to us from the GIS" (Strickler and Watson 1993). During this last year, we examined the GIS vegetation information more closely. We became increasingly suspicious of the accuracy of the vegetation map, even on a large scale. We had maps printed of almost half of our sites and rigorously checked them in the field. Mis-identification of vegetation was most prevalent within the shrub types: but we also found errors in misclassifying grass and highly disturbed areas as sagebrush and vice versa. The magnitude of the errors ranged from 0 to 100% incorrect, and no consistent pattern in the errors could be discerned. Almost 25% of our sites were mis-classified in the 1993 vegetation database. Using data collected during the field checks, we adjusted the estimates of percent cover of each vegetation type and reclassified our sites, retaining the habitat categories proposed by Knick et al. (1992) and used by us last year. The mutually exclusive categories are: agriculture - any site with ≥15% cultivated or irrigated land, regardless of other vegetation types; sagebrush - ≥15% high or medium density sagebrush or rabbitbrush; shadscale - ≥15% high or medium density shadscale or winterfat; grass/exotic annuals - <15% shrub cover; shrub mosaic - ≥15%of both sagebrush and shadscale-associated shrubs.

Time of Day.-- We tested the interaction between habitat class and diurnal period with a multivariate, repeated measures permutation procedure (Slauson et al. 1991). We ran applicable univariate tests for main effects and subeffects depending upon the significance of the 2-way interaction, with Bonferroni adjustments for multiple comparisons, where appropriate, applied as described above. We ran separate analyses on each season and on each common species.

Habitat Use vs. Availability.-- We evaluated use and availability of specific vegetation types by comparing the habitat composition of used sites with that of available sites (used + unused). Each site was characterized by the percent cover of 7 vegetation types: agriculture, rabbitbrush, sagebrush, shadscale, winterfat, grass, and highly disturbed. We also classified each site as to the presence/absence of rocks, fences, and power lines. We determined presence or absence of each bird species for each site in each season. We ran MRPP for each bird species, using the excess group option (excess = 0) (Cade and Hoffman 1990; Slauson et al. 1991; B.S. Cade, NBS, pers. commun.), to calculate probabilities that the habitat composition at used sites could have been selected by chance from available sites. Small *P* values indicate that the habitat composition at used sites was significantly different, for at least one vegetation type, from what was generally available at all sites. Because vegetation values were percentages and rock, fence, and power line data were categorical, we ran separate MRPP analyses for each type of data.

Agricultural Lands.-- To evaluate the effect of private agricultural lands outside the OTA on our counts, we classified all non-OTA sites as near agriculture (near-ag) if there was irrigated and/or cultivated land (pasture or intensely managed) within 2 km of the center point of the site, and no agriculture (non-ag) if there was no agriculture within 2 km of the center point. Again we noted errors in the identification of agriculture on the vegetation map. A new agriculture map was obtained by the RRTAC GIS department. Field checks proved this map to be highly accurate. Because 17 sites changed their near-ag designation, we reran all previous analyses.

We directly compared counts at near-ag sites and non-ag sites during different times of day using MRPP. To assess the influence of agricultural lands

on the OTA/non-OTA comparisons, we omitted all near-ag sites and ran the MRPP, as described above, testing for the interaction of OTA and diurnal period. Different results between this test and the test in which agricultural lands were included indicate that agricultural practices have a strong effect on the distribution of raptors and ravens in the ISA.

RESULTS

Raptor Detections and Seasonal Patterns

We conducted 1,698 point counts between 16 July 1993 and 15 July 1994: 627 at OTA sites and 1,071 at non-OTA sites. Seventy-two percent (2,254) of the 3,124 birds detected at these counts were common ravens. We recorded 15 species of raptors (listed in order of abundance; Appendix A): northern harrier (202), golden eagle (171), prairie falcon (112), red-tailed hawk (94), rough-legged hawk (79), Swainson's hawk (42), American kestrel (*Falco sparverius*) (37), ferruginous hawk (31), turkey vulture (*Cathartes aura*) (28), burrowing owl (*Speotyto cunicularia*) (18), short-eared owl (*Asio flammeus*) (7), merlin (*Falco columbarius*) (4), sharp-shinned hawk (*Accipiter striatus*) (3), bald eagle (*Haliaeetus leucocephalus*) (3), Cooper's hawk (*Accipiter cooperii*) (2).

In previous years, the breeding seasons have always recorded a higher number of birds than the dry or winter seasons (Appendix A). This year the mean numbers of all birds seen in the winter and breeding seasons were similar with 2.08 birds/count recorded in the 1993-94 winter and 2.04 birds/count in the 1994 breeding. The 1993 dry season recorded not only the lowest number of birds of the year but also the lowest for the entire study. Raven numbers dropped by 25% from a high in the winter (1.61 ravens/count) to only 1.21 ravens/count in the breeding season, almost equal to their dry season low of 1.16 ravens/count. Raptors as a group followed the same annual cyclical pattern of previous years with a dry season low of 0.24 raptors/count, rising to 0.47 in the winter and 0.82 raptors/count in the 1994 breeding season. Northern harrier, prairie falcon, ferruginous hawk, and rough-legged hawk numbers were all lower than in previous respective seasons (Appendix A). Red-tailed hawk and Swainson's hawk counts were generally low but not as low as they have been in past seasons. Golden eagles were recorded in their highest numbers ever in the 1993-94 winter season (82) but fell to only 61 birds in the 1994 breeding season.

As in previous years, the pattern of raptor numbers rising in the third cycle of winter season to a high in the first cycle of breeding season with a gradual drop in numbers as the breeding season progressed was clear; however, the generally lower numbers in 1993-94 were also strongly evident (Figs. 1a-1c).

Raptor (Fig. 2a) and raven (Fig. 2b) numbers through the 1994 breeding season showed quite different patterns. Raptors exhibited remarkably similar patterns over the season in both the OTA and non-OTA areas. Numbers changed very little between cycle 1 and cycle 2 (< 1% in both areas), but showed a sharp decrease between cycle 2 and cycle 3 (56% in the OTA and 42% in non-OTA). We recorded 0.83 raptors / count in the OTA in cycle 1 and 0.84 raptors / count in cycle 2 followed by 0.37 raptors / count in cycle 3. In the non-OTA, raptor numbers were, as usual, higher with 1.09 raptors / count in cycle 1, 1.03 in cycle 2, and 0.60 in cycle 3. Ravens started the 1994 breeding season with lower numbers than any previous breeding season. Raven numbers, inside and outside the OTA, both fell 36% from cycle 1 (1.39 in OTA; 2.02 in non-OTA) to cycle 2 (0.89 in OTA; 1.29 in non-OTA). In cycle 3 the mean number of ravens fell 78% in the OTA to 0.20; whereas in the non-OTA the species decreased to 1.01, only a 22% drop.

Raptor Detections and Time of Day

Dry 1993.-- We recorded a lower number of birds during dry 1993 than any previous season. Only common ravens and red-tailed hawks showed a significant interaction between time of day and OTA (ravens - $d = 2.02$, $P = 0.00012$; red-tailed hawks - $d = 2.08$, $P = 0.01$) indicating that each

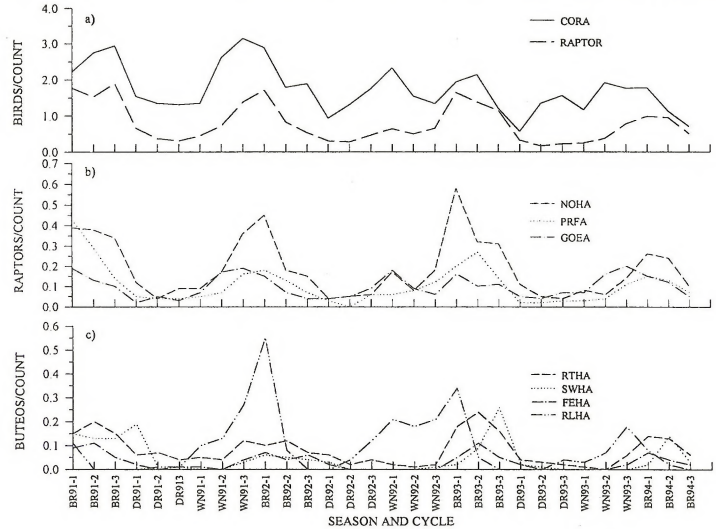

Fig. 1. Mean counts for raptors (a), common ravens (CORA)(a), northern harriers (NOHA)(b), prairie falcons (PRFA)(b), golden eagles (GOEA)(b), red-tailed hawks (RTHA)(c), Swainson's hawks (SWHA)(c), ferruginous hawks (FEHA)(c), and rough-legged hawks (RLHA)(c) from April 1991 (breeding 1991, cycle 1) through 15 July 1994 (breeding 1994, cycle 3) in the integration study area of the Snake River Birds of Prey Area.

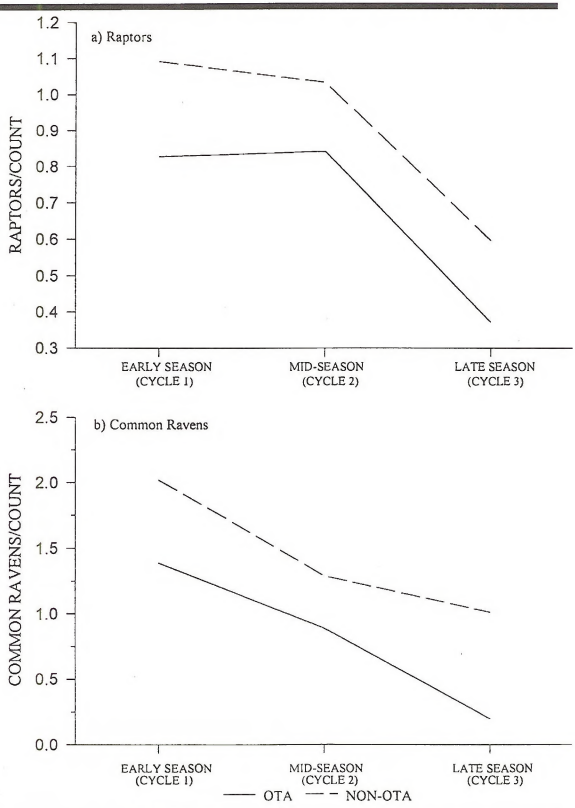

Fig. 2. Mean counts for raptors (a) and ravens (b) inside and outside the OTA during the 1994 breeding season.

species was using the OTA and non-OTA areas differently throughout the day. Ravens were more numerous at non-OTA sites at all times of day. These differences were significant in the morning (d = 1.23, P = 0.014) and evening (d = 3.47, P = 0.0004), and very close to significant in the afternoon (d = 1.40, P = 0.026) (Table 1). Despite very different patterns of diurnal use in the OTA and non-OTA, none of the period contrasts within the OTA and non-OTA were significant. Raven numbers were highest in the OTA in the morning and afternoon, and dropped sharply in the evening. In the non-OTA, raven numbers were lowest in the mornings and highest in the evenings. Only 17 red-tailed hawks were recorded in dry 1993 (Appendix A), of which only 1 was recorded in the OTA, thus giving the significant interaction in time of day and OTA (Table 2). No diurnal contrasts were significant. Within the non-OTA, red-tailed hawk diurnal use was consistent throughout the day. For all other species, no significant differences in numbers inside and outside the OTA or diurnal use were found (Tables 3, 4, and 5). Swainson's hawk, ferruginous hawk, and rough-legged hawk numbers were too low for adequate analysis (Tables 6-8).

The exclusion of non-OTA near-ag sites from the OTA vs. non-OTA comparison did not change the results very much; however, non-OTA means for most species dropped. The mean number of golden eagles recorded in the morning and evening in the non-OTA dropped; whereas, the afternoon means increased to create a significant difference in diurnal use (Table 5). We recorded more golden eagles in the afternoon than in either the morning (d = 0.46, P = 0.001) or evening (d = 0.82, P = 0.017).

Winter 1993-94.-- Observations have been conducted over 3 winter seasons (Appendix A). The 1,175 birds recorded in winter 1993-94 was the lowest recorded in any winter season. We recorded more golden eagles than ever before but substantially fewer of other species, especially rough-legged hawks. We found no significant interaction for any species, indicating that the OTA and non-OTA were used similarly throughout the day (Tables 2-8). Only ravens showed a significant difference in numbers between the OTA and non-OTA (d = 1.74, P = 0.007), and there were no differences in their use of the 3 diurnal periods. We recorded equally low numbers of northern harriers, prairie falcons, red-tailed hawks, and rough-legged hawks inside and outside the OTA and found no difference in numbers throughout the day. Golden eagle numbers were similar inside and outside the OTA, and eagles used the diurnal periods proportionately. Swainson's hawk and ferruginous hawk numbers were too low to analyze.

Exclusion of the non-OTA near-ag sites generally decreased the overall non-OTA means for all species. The significant difference in numbers of ravens inside and outside the OTA disappeared as the raven non-OTA mean decreased from 1.78 to 1.57 (Table 1). Again, no significant differences in diurnal use were recorded for any species; however, some of the changes were interesting. Mean numbers declined in all time periods for ravens (Table 1), but did not change for golden eagles (Table 3). The mean number of northern harriers declined in the morning and evening periods but increased in the afternoon (Table 3). Prairie falcon (Table 4) and red-tailed hawk (Table 2) means decreased slightly in the morning and evening periods with a larger decline in the afternoon counts. The afternoon mean count of rough-legged hawks also declined with the exclusion of near-ag sites; however, morning and evening means marginally increased (Table 8).

Breeding 1994.-- Only ferruginous hawks showed a significant interaction term (d = 2.07, P = 0.027, Table 7) in the 1994 breeding season. We recorded more ferruginous hawks inside than outside the OTA during the evening (d = 0.10, P = 0.009). Differences in diurnal use within the OTA and non-OTA were not significant, but evening counts in the OTA were still relatively high (Table 7). Ravens (Table 1) and red-tailed hawks (Table 4) were significantly higher in the non-OTA. Again, most species showed no significant differences in their use of the diurnal periods; however, the difference between raven counts in the morning and afternoon was very close to significant (d = 3.33, P = 0.019).

Exclusion of near-ag sites in the non-OTA data set caused some changes in the OTA/non-OTA comparisons. Both the significant interaction and the difference in evening counts of ferruginous hawks were lost (Table 7). The number of

Table 1. Mean counts of common ravens at OTA and non-OTA sites and at all Integrated Study Area (ISA) sites during the last 3 seasons. The "non-OTA sites without ag" category excludes all non-OTA sites within 2 km of agriculture. (M = morning; A = afternoon; E = evening).

	All ISA sites			OTA sites				Non-OTA sites				Non-OTA sites without ag			
Season	M	A	E	Total	M	A	E	Total	M	A	E	Total	M	A	E
Dry 1993															
N	189	189	189	210	70	70	70	357	119	119	119	219	73	73	73
Mean	0.73	0.81	1.93	0.28	0.31[a]	0.36	0.17[a]	1.68	0.98[a]	1.08	2.96[a]	1.26	0.81	0.37	2.60
SD	2.29	2.19	7.85	0.76	0.75	0.90	0.59	6.10	2.80	2.64	9.75	6.68	3.29	1.26	10.95
Winter 1993-94															
N	188	188	188	207	69	69	69	357	119	119	119	219	73	73	73
Mean	1.59	1.09	2.17	1.33[a]	1.28	0.88	1.84	1.78[a]	1.77	1.20	2.36	1.57	1.23	1.04	2.44
SD	3.00	1.56	5.29	3.88	3.83	1.40	5.33	3.50	2.39	1.64	5.28	3.78	1.94	1.40	6.04
Breeding 1994															
N	189	189	189	210	70	70	70	357	119	119	119	219	73	73	73
Mean	1.51	0.94	1.19	0.82[a]	1.13	0.46	0.89	1.44[a]	1.74	1.22	1.36	1.01	1.08	0.79	1.15
SD	3.53	1.40	2.41	1.97	1.44	0.82	2.97	2.89	4.30	1.58	2.01	1.73	1.79	1.30	2.03

[a] OTA/non-OTA comparison: P < 0.05
[b] Morning/afternoon comparison: P < 0.017
[c] Morning/evening comparison: P < 0.017
[d] Afternoon/evening comparison: P < 0.017
[e] OTA/non-OTA comparison in morning period: P < 0.017
[f] OTA/non-OTA comparison in afternoon period: P < 0.017
[g] OTA/non-OTA comparison in evening period: P < 0.017

Table 2. Mean counts of red-tailed hawks at OTA and non-OTA sites and at all Integrated Study Area (ISA) sites during the last 3 seasons. The "non-OTA sites without ag" category excludes all non-OTA sites within 2 km of agriculture. (M = morning; A = afternoon; E = evening).

	All ISA sites			OTA sites				Non-OTA sites				Non-OTA sites without ag			
Season	M	A	E	Total	M	A	E	Total	M	A	E	Total	M	A	E
Dry 1993															
N	189	189	189	210	70	70	70	357	119	119	119	219	73	73	73
Mean	0.02	0.04	0.03	0	0	0	0.01	0.04	0.03	0.06	0.04	0.02	0.03	0.01	0.03
SD	0.14	0.19	0.18	0.07	0	0	0.12	0.21	0.06	0.24	0.20	0.15	0.16	0.12	0.02
Winter 1993-94															
N	188	188	188	207	69	69	69	357	119	119	119	219	73	73	73
Mean	0.03	0.04	0.02	0.02	0.01	0.03	0.01	0.03	0.03	0.04	0.02	0.02	0.01	0.04	0.01
SD	0.16	0.22	0.13	0.17	0.12	0.24	0.12	0.17	0.18	0.20	0.13	0.15	0.12	0.20	0.12
Breeding 1994															
N	189	189	189	210	70	70	70	357	119	119	119	219	73	73	73
Mean	0.10	0.14	0.09	0.07[a]	0.04	0.10	0.06	0.13[a]	0.13	0.17	0.11	0.09	0.10	0.10	0.07
SD	0.33	0.44	0.29	0.27	0.20	0.35	0.23	0.40	0.38	0.49	0.31	0.30	0.34	0.30	0.25

[a] OTA/non-OTA comparison: P < 0.05
[b] Morning/afternoon comparison: P < 0.017
[c] Morning/evening comparison: P < 0.017
[d] Afternoon/evening comparison: P < 0.017
[e] OTA/non-OTA comparison in morning period: P < 0.017
[f] OTA/non-OTA comparison in afternoon period: P < 0.017
[g] OTA/non-OTA comparison in evening period: P < 0.017

Table 3. Mean counts of northern harriers at OTA and non-OTA sites and at all Integrated Study Area (ISA) sites during the last 3 seasons. The "non-OTA sites without ag" category excludes all non-OTA sites within 2 km of agriculture. (M = morning; A = afternoon; E = evening).

	All ISA sites			OTA sites				Non-OTA sites				Non-OTA sites without ag			
Season	M	A	E	Total	M	A	E	Total	M	A	E	Total	M	A	E
Dry 1993															
N	189	189	189	210	70	70	70	357	119	119	119	219	73	73	73
Mean	0.08	0.05	0.06	0.06	0.11	0.01	0.04	0.07	0.06	0.07	0.08	0.05	0.07	0.05	0.04
SD	0.27	0.21	0.24	0.23	0.32	0.12	0.20	0.25	0.24	0.25	0.27	0.23	0.25	0.23	0.20
Winter 1993-94															
N	188	188	188	207	69	69	69	357	119	119	119	219	73	73	73
Mean	0.09	0.10	0.11	0.10	0.06	0.12	0.13	0.09	0.10	0.08	0.09	0.07	0.07	0.10	0.05
SD	0.30	0.31	0.31	0.32	0.24	0.37	0.34	0.30	0.33	0.28	0.29	0.26	0.25	0.30	0.23
Breeding 1994															
N	189	189	189	210	70	70	70	357	119	119	119	219	73	73	73
Mean	0.21	0.17	0.21	0.17	0.21	0.14	0.16	0.21	0.21	0.18	0.24	0.12	0.11	0.08	0.18
SD	0.55	0.43	0.58	0.47	0.56	0.39	0.44	0.56	0.55	0.45	0.65	0.40	0.36	0.28	0.54

[a] OTA/non-OTA comparison: $P < 0.05$
[b] Morning/afternoon comparison: $P < 0.017$
[c] Morning/evening comparison: $P < 0.017$
[d] Afternoon/evening comparison: $P < 0.017$
[e] OTA/non-OTA comparison in morning period: $P < 0.017$
[f] OTA/non-OTA comparison in afternoon period: $P < 0.017$
[g] OTA/non-OTA comparison in evening period: $P < 0.017$

Table 4. Mean counts of prairie falcons at OTA and non-OTA sites and at all Integrated Study Area (ISA) sites during the last 3 seasons. The "non-OTA sites without ag" category excludes all non-OTA sites within 2 km of agriculture. (M = morning; A = afternoon; E = evening).

	All ISA sites			OTA sites				Non-OTA sites				Non-OTA sites without ag			
Season	M	A	E	Total	M	A	E	Total	M	A	E	Total	M	A	E
Dry 1993															
N	189	189	189	210	70	70	70	357	119	119	119	219	73	73	73
Mean	0.03	0.03	0.01	0.02	0.01	0.06	0	0.02	0.03	0.02	0.01	0.01	0.03	0.01	0
SD	0.16	0.23	0.07	0.21	0.12	0.34	0	0.14	0.18	0.13	0.09	0.12	0.16	0.12	0
Winter 1993-94															
N	188	188	188	207	69	69	69	357	119	119	119	219	73	73	73
Mean	0.04	0.07	0.07	0.04	0.03	0.03	0.07	0.07	0.05	0.09	0.07	0.04	0.04	0.03	0.05
SD	0.23	0.29	0.29	0.25	0.24	0.17	0.31	0.29	0.22	0.34	0.28	0.20	0.20	0.16	0.23
Breeding 1994															
N	189	189	189	210	70	70	70	357	119	119	119	219	73	73	73
Mean	0.11	0.11	0.13	0.09	0.10	0.13	0.04	0.13	0.12	0.10	0.18	0.11	0.11	0.07	0.15
SD	0.33	0.33	0.41	0.29	0.30	0.34	0.20	0.39	0.35	0.33	0.48	0.37	0.31	0.30	0.46

[a] OTA/non-OTA comparison: $P < 0.05$
[b] Morning/afternoon comparison: $P < 0.017$
[c] Morning/evening comparison: $P < 0.017$
[d] Afternoon/evening comparison: $P < 0.017$
[e] OTA/non-OTA comparison in morning period: $P < 0.017$
[f] OTA/non-OTA comparison in afternoon period: $P < 0.017$
[g] OTA/non-OTA comparison in evening period: $P < 0.017$

Table 5. Mean counts of golden eagles at OTA and non-OTA sites and at all Integrated Study Area (ISA) sites during the last 3 seasons. The "non-OTA sites without ag" category excludes all non-OTA sites within 2 km of agriculture. (M = morning; A = afternoon; E = evening).

	All ISA sites			OTA sites				Non-OTA sites				Non-OTA sites without ag			
Season	M	A	E	Total	M	A	E	Total	M	A	E	Total	M	A	E
Dry 1993															
N	189	189	189	210	70	70	70	357	119	119	119	219	73	73	73
Mean	0.04	0.08	0.04	0.04	0	0.10	0.01	0.06	0.18	0.07	0.05	0.04	0.01	0.08	0.03
SD	0.19	0.29	0.22	0.22	0	0.35	0.12	0.25	0.24	0.25	0.26	0.20	0.12	0.28	0.16
Winter 1993-94															
N	188	188	188	207	69	69	69	357	119	119	119	219	73	73	73
Mean	0.14	0.15	0.14	0.14	0.17	0.16	0.10	0.15	0.13	0.14	0.17	0.16	0.17	0.15	0.15
SD	0.45	0.39	0.42	0.43	0.57	0.37	0.30	0.41	0.36	0.40	0.48	0.40	0.33	0.40	0.46
Breeding 1994															
N	189	189	189	210	70	70	70	357	119	119	119	219	73	73	73
Mean	0.12	0.11	0.10	0.10	0.13	0.10	0.06	0.11	0.11	0.12	0.12	0.09	0.11	0.05	0.10
SD	0.38	0.32	0.34	0.31	0.38	0.30	0.23	0.37	0.39	0.32	0.39	0.33	0.39	0.23	0.34

[a] OTA/non-OTA comparison: P < 0.05
[b] Morning/afternoon comparison: P < 0.017
[c] Morning/evening comparison: P < 0.017
[d] Afternoon/evening comparison: P < 0.017
[e] OTA/non-OTA comparison in morning period: P < 0.017
[f] OTA/non-OTA comparison in afternoon period: P < 0.017
[g] OTA/non-OTA comparison in evening period: P < 0.017

Table 6. Mean counts of Swainson's hawks at OTA and non-OTA sites and at all Integrated Study Area (ISA) sites during the last 3 seasons. The "non-OTA sites without ag" category excludes all non-OTA sites within 2 km of agriculture. (M = morning; A = afternoon; E = evening).

	All ISA sites			OTA sites				Non-OTA sites				Non-OTA sites without ag			
Season	M	A	E	Total	M	A	E	Total	M	A	E	Total	M	A	E
Dry 1993															
N	189	189	189	210	70	70	70	357	119	119	119	219	73	73	73
Mean	0.01	0.02	0	0	0	0	0	0.02	0.02	0.03	0	0.01	0.01	0.03	0
SD	0.10	0.14	0	0	0	0	0	0.13	0.13	0.18	0	0.12	0.12	0.16	0
Winter 1993-94															
N	188	188	188	207	69	69	69	357	119	119	119	219	73	73	73
Mean	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Breeding 1994															
N	189	189	189	210	70	70	70	357	119	119	119	219	73	73	73
Mean	0.06	0.08	0.04	0.04	0.07	0.03	0.01	0.08	0.06	0.12	0.06	0.03	0.05	0.01	0.03
SD	0.28	0.39	0.23	0.22	0.31	0.17	0.12	0.35	0.27	0.47	0.27	0.18	0.23	0.12	0.16

[a] OTA/non-OTA comparison: P < 0.05
[b] Morning/afternoon comparison: P < 0.017
[c] Morning/evening comparison: P < 0.017
[d] Afternoon/evening comparison: P < 0.017
[e] OTA/non-OTA comparison in morning period: P < 0.017
[f] OTA/non-OTA comparison in afternoon period: P < 0.017
[g] OTA/non-OTA comparison in evening period: P < 0.017

Table 7. Mean counts of ferruginous hawks at OTA and non-OTA sites and at all Integrated Study Area (ISA) sites during the last 3 seasons. The "non-OTA sites without ag" category excludes all non-OTA sites within 2 km of agriculture. (M = morning; A = afternoon; E = evening).

	All ISA sites			OTA sites				Non-OTA sites				Non-OTA sites without ag			
Season	M	A	E	Total	M	A	E	Total	M	A	E	Total	M	A	E
Dry 1993															
N	189	189	189	210	70	70	70	357	119	119	119	219	73	73	73
Mean	0.02	0.01	0	0.01	0.03	0.01	0	0	0.01	0	0	0	0.01	0	0
SD	0.13	0.07	0	0.12	0.17	0.12	0	0.05	0.09	0	0	0.07	0.12	0	0
Winter 1993-94															
N	188	188	188	207	69	69	69	357	119	119	119	219	73	73	73
Mean	0.01	0.01	0.01	0	0	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
SD	0.07	0.07	0.07	0	0	0	0	0.09	0.09	0.09	0.09	0.12	0.12	0.12	0.12
Breeding 1994															
N	189	189	189	210	70	70	70	357	119	119	119	219	73	73	73
Mean	0.03	0.05	0.05	0.07	0.03	0.06	0.11*	0.03	0.03	0.04	0.02*	0.03	0.03	0.04	0.03
SD	0.19	0.24	0.25	0.27	0.17	0.23	0.36	0.20	0.20	0.24	0.13	0.22	0.23	0.26	0.16

* OTA/non-OTA comparison: P < 0.05
† Morning/afternoon comparison: P < 0.017
‡ Morning/evening comparison: P < 0.017
‡ Afternoon/evening comparison: P < 0.017

* OTA/non-OTA comparison in morning period: P < 0.017
† OTA/non-OTA comparison in afternoon period: P < 0.017
* OTA/non-OTA comparison in evening period: P < 0.017

Table 8. Mean counts of rough-legged hawks at OTA and non-OTA sites and at all Integrated Study Area (ISA) sites during the last 3 seasons. The "non-OTA sites without ag" category excludes all non-OTA sites within 2 km of agriculture. (M = morning; A = afternoon; E = evening).

	All ISA sites			OTA sites				Non-OTA sites				Non-OTA sites without ag			
Season	M	A	E	Total	M	A	E	Total	M	A	E	Total	M	A	E
Dry 1993															
N	189	189	189	210	70	70	70	357	119	119	119	219	73	73	73
Mean	0.21	0.01	0.01	0	0	0	0	0.02	0.03	0.02	0.02	0.01	0	0.01	0.03
SD	0.14	0.10	0.10	0	0	0	0	0.15	0.18	0.13	0.13	0.12	0	0.12	0.16
Winter 1993-94															
N	188	188	188	207	69	69	69	357	119	119	119	219	73	73	73
Mean	0.09	0.09	0.10	0.09	0.09	0.01	0.11	0.14	0.09	0.13	0.08	0.12	0.14	0.11	0.12
SD	0.32	0.35	0.36	0.29	0.28	0.12	0.40	0.37	0.34	0.43	0.33	0.40	0.42	0.39	0.41
Breeding 1994															
N	189	189	189	210	70	70	70	357	119	119	119	219	73	73	73
Mean	0.03	0.06	0.02	0.04	0.04	0.06	0.01	0.03	0.02	0.06	0.02	0.03	0.01	0.05	0.01
SD	0.16	0.26	0.13	0.20	0.20	0.23	0.12	0.19	0.13	0.27	0.13	0.16	0.12	0.23	0.12

* OTA/non-OTA comparison: P < 0.05
† Morning/afternoon comparison: P < 0.017
‡ Morning/evening comparison: P < 0.017
‡ Afternoon/evening comparison: P < 0.017

* OTA/non-OTA comparison in morning period: P < 0.017
† OTA/non-OTA comparison in afternoon period: P < 0.017
* OTA/non-OTA comparison in evening period: P < 0.017

ferruginous hawks in the evening increased in the non-OTA with the exclusion of near-ag sites. The significant difference in ravens (Table 1) and red-tailed hawks (Table 2) inside and outside the OTA also disappeared. Whereas numbers of ravens generally dropped with the exclusion of near-ag sites, morning counts became significantly higher than afternoon counts (d = 2.57, P = 0.0042). Northern harrier numbers dropped substantially at non-OTA sites, but declined fairly evenly across the diurnal periods (Table 2). Prairie falcon (Table4), golden eagle (Table 5), ferruginous hawk (Table 7), and rough-legged hawk (Table 8) numbers did not change greatly with the exclusion of near-ag sites. Red-tailed hawks (Table 2) and Swainson's hawks (Table 6) declined over all periods but showed the greatest decline in afternoon counts.

Raptor Detections and Military Training

Military training occurred at the OTA member of 24 (12.7%) of 189 pairs of counts conducted in the 1993-94 non-breeding seasons (dry 1993 and winter 1993-94; Fig.3). Only 6 of those pairs had different raptor presence/absence records and were used in the contingency table analysis. We conducted 165 observations during no military activity, of which 105 had similar presence/absence results. There was no significant difference between the number of counts with raptors on the non-OTA sites only and on OTA sites only during military activity (non-OTA - n = 4; OTA - n = 2) and during no military activity (non-OTA - n = 36; OTA - n = 24) (G^2_1 = 0.10, P = 0.75). Of the 18 pairs of observations with military activity and similar presence/absence results, only 2 pairs (11%) had non-zero raptor counts. Likewise, in the no military activity data set, only 12% (13) of the pairs contained non-zero counts. During the 1994 breeding season, only 17 of 96 pairs (17.7%) were observed with military activity. Nine pairs had dissimilar presence/absence results: 3 pairs recorded raptor presence only at the OTA site and 6 pairs with raptors only at the non-OTA site. Of the 8 pairs with similar results, 38% were non-zero counts. Seventy-nine counts had no military activity present: 34 had different presence/absence results, and 45 had similar results. Twelve of the 34 pairs with dissimilar results recorded raptors at the OTA site only, and 22 had raptors at the non-OTA site only. Twenty of the pairs with similar results were non-zero counts. There was no significant difference in the presence or absence of raptors at pairs of sites during times of military activity (OTA - n = 3; non-OTA - n = 6) and no military activity (OTA - n = 12; non-OTA - n = 22) (G^2_1 = 0.012, P = 0.91).

Following the pattern of previous years, counts at paired sites in breeding 1994 and non-breeding 1993-94 seasons showed higher raptor numbers at non-OTA sites, regardless of presence of military activity at the OTA site (Table 9). MRPP contrast analyses supported the Wilcoxon matched pair and 2-sample test results reported last year (Strickler and Watson 1993). We found no significant differences in the simultaneously observed pair contrasts of raptor numbers inside and outside the OTA with military activity (contrast 1 vs. 2) and with no military activity (contrast 3 vs. 4) in any season or year (see Methods section for definition of contrasts). Data for the within OTA contrast (1 vs. 3) and within non-OTA contrast (2 vs. 4) were not observed simultaneously, but were collected over the entire season. The results, therefore, are subject to the complications of within season timing of military activity and raptor abundance and must be interpreted relative to each other and not individually. The breeding 1992 (d = 0.90, P = 0.004), 1993 (d = 1.03, P = 0.004), and non-breeding 1991 (d = 0.40, P = 0.0006) and 1992 (d = 0.26, P = 0.002) seasons all showed significant results for the contrast comparing sites with and without military activity in the OTA (contrast 1 vs. 3) and non-significant results for the similar non-OTA contrast (2 vs. 4). Because timing, habitat composition and weather conditions were similar for both the OTA and non-OTA contrasts, we conclude from the dissimilar contrast results that military activity was influencing the numbers of raptors seen on the OTA during military activity in those seasons. The breeding 1991 and 1994 seasons did not show significant results in either contrast, 1 vs. 3 or 2 vs. 4; and so, we conclude that military activity was not influencing the raptor counts in those seasons. Non-breeding 1993 results were significant for both the within OTA contrast (1 vs. 3) (d = 0.30, P = 0.02) and non-OTA contrast (2 vs. 4) (d = 0.42, P = 0.005). The OTA sites with no military activity had significantly higher numbers of raptors than OTA sites with military activity. The non-OTA comparison showed

Table 9. Mean counts of all raptor species at OTA and non-OTA paired sites in the presence or absence of military activity (MA) during the 1991, 1992, 1993, and 1994 breeding seasons and the 1991, 1992, and 1993 combined non-breeding (dry and winter) seasons. Significant differences ($P \leq 0.0125$) are indicated between raptor counts within the OTA ([a]) (military activity vs. no military activity) and within the non-OTA ([b]) sites in that season.

		Paired sites WITH MA		Paired sites WITH NO MA	
Season		OTA	NON-OTA	OTA	NON-OTA
Breeding 1991	N	11	11	32	32
	MEAN	2.04	2.23	1.34	1.67
	SD	1.35	1.47	1.25	1.23
Breeding 1992	N	17	17	32	32
	MEAN	0.59	0.68	1.03	0.99
	SD	1.12	0.92	0.75	0.83
Breeding 1993	N	17	17	32	32
	MEAN	0.65	1.41	1.49	1.58
	SD	0.72	1.13	1.14	1.05
Breeding 1994	N	14	14	32	32
	MEAN	0.53	0.68	0.78	1.09
	SD	0.75	0.67	0.87	1.03
Non-breeding 1991	N	17	17	32	32
	MEAN	0.25	1.06	0.58	0.8
	SD	0.43	1.36	0.34	0.67
Non-breeding 1992	N	9	9	32	32
	MEAN	0.11	0.94	0.29	0.45
	SD	0.33	1.33	0.25	0.38
Non-breeding 1993	N	15	15	32	32
	MEAN	0.14	0.26	0.31	0.45
	SD	0.29	0.56	0.29	0.37

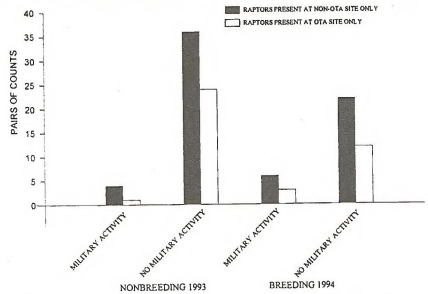

Fig. 3. Occurrence of raptors at only OTA and only non-OTA sites during simultaneous counts of paired sites in the integration study area in the presence and absence of military activity during the 1993-94 non-breeding and the 1994 breeding seasons.

significantly more raptors at non-OTA sites paired with OTA sites that had no military activity than at non-OTA sites paired with OTA sites with military activity. However, no military activity occurred at non-OTA sites; therefore, some other factor, such as habitat differences, weather conditions, or seasonal timing of raptor abundance, was influencing raptor counts. These same factors may have influenced the counts at OTA sites, so we cannot conclude that military activity was influencing the raptor counts at OTA sites with military activity in the non-breeding 1993 season.

We tended to record more zero raptor counts in the presence of bivouacs and vehicles in breeding 1994 than at OTA sites with no military activity (Fig. 4). We observed only 5 sites with air traffic and 1 site with firing activity in the 1994 breeding season. We observed the same trend in percent zero counts in the 1993 dry season, with a greater proportion of zero counts recorded at sites with military activity than at sites with no military activity. Although this pattern has been consistent in every season (Strickler and Watson 1993), none of the results for the 1994 breeding and 1993 dry seasons were significant (Fig. 4). However, in the 1993 dry season, the distributions of the number of raptors observed in association with bivouacs ($G^2_1 = 2.69$, $P = 0.10$), vehicles ($G^2_1 = 3.61$, $P = 0.057$), and firing ($G^2_1 = 3.45$, $P = 0.063$) were very close to being significantly different from the distribution of raptor numbers observed with no military activity.

Raptor Detections, Habitat and Time of Day

Field-correcting the vegetation database substantially changed the number of sites classified in the 5 habitat categories. Sagebrush-associated sites decreased from 89 to 66, shadscale-associated sites decreased from 15 to 12, grass/exotic annual sites increased from 69 to 76, and shrub mosaic sites increased from 7 to 18. Last year we reported no significant interactions between habitat class and time of day in any season (Strickler and Watson 1993). Re-analyzing all raptor habitat associations using the corrected vegetation data changed the results dramatically (Tables 10-17).

Common Raven.-- Ravens showed significant habitat*time of day interactions in all 3 dry seasons and the 1993 breeding season (Table 10). In all seasons, except breeding 1994, ravens showed a significant difference in their association with the 5 habitat classes. In breeding 1991, ravens were most strongly associated with sagebrush sites; in breeding 1992 and 1993, they were positively associated with both sagebrush and agriculture sites. In all non-breeding seasons, ravens were most strongly associated with agriculture sites. Diurnal use patterns within each habitat differed depending on the type of season. The general pattern of association in the breeding seasons, except breeding 1993, was for ravens to be most numerous in the agriculture and sagebrush sites in the mornings and afternoons. In all other habitats, their highest numbers were recorded during the morning and/or evening. However, in breeding 1991, ravens were most numerous in all habitats except sagebrush during the afternoon. In breeding 1993, ravens associated with agriculture sites during the mornings and afternoons, and sagebrush in the evening. Ravens were at shadscale and shrub mosaic sites most commonly in morning and evening. They were most numerous at grass sites in the morning and afternoon. Diurnal use patterns in the non-breeding seasons reflected a high presence at agriculture sites at all times of day. Ravens were recorded most often in the other habitats during the evenings in the winter seasons and during the mornings or evenings in the dry seasons.

Northern Harrier.-- Northern harriers showed a significant interaction between habitat and time of day in all but 1 non-breeding season, and in breeding season 1991 and 1992 (Table 11). In the 1991, 1992, and 1993 breeding seasons, harriers were associated with agriculture and sagebrush sites, and strongly avoided shadscale sites. As with ravens, northern harriers showed no significant association with any habitat in breeding 1994. In the dry seasons, harriers did not show a significant association with any habitat in 1991 or 1993, but they were strongly associated with agriculture in dry 1992. Harriers seemed to avoid shadscale and shrub mosaic sites in winter 1991, showed no strong habitat associations in winter 1992, and avoided grass and mosaic sites in winter 1993. Diurnal patterns in the breeding seasons tended to follow the same pattern in all habitats. More harriers were

Table 10. Species means by habitat (agriculture, sagebrush, shadscale, grass/exotic annuals, shrub mosaic) and diurnal period (morning, afternoon, evening) within habitats for common ravens over the entire study period, April 1991 - July 1994. Interaction and habitat terms are *P*-values where $P \leq 0.05$ is the accepted significant level (*).

	BREEDING				DRY			WINTER		
	1991	1992	1993	1994	1991	1992	1993	1991	1992	1993
Interaction *P*-value	0.06	0.30	0.03*	0.92	0.00001*	0.0003*	0.0005*	0.26	0.11	0.16
Habitat *P*-value	0.00009*	0.01*		0.08				0.04*	0.0009*	0.009*
Agric	2.31	3.61	3.16	1.71	5.87	3.67	3.67	3.58	3.47	2.26
Morn	1.82	5.94	4.47	1.65	2.72	3.12	2.00	2.13	2.12	3.47
Aft	3.41	2.77	3.59	1.82	3.83	4.29	3.18	4.63	2.12	1.47
Even	1.71	2.12	1.41	1.65	11.06	3.59	5.82	4.00	6.18	1.82
Sagebrush	3.94	2.51	2.29	1.16	0.91	1.59	0.73	2.19	2.06	1.30
Morn	4.43	3.05	1.89	1.44	1.43	1.44	0.42	1.92	1.55	1.05
Aft	3.37	2.53	1.76	0.97	0.83	1.23	0.64	1.79	1.30	1.26
Even	4.00	1.97	3.23	1.08	0.46	2.09	1.14	2.87	3.33	1.61
Shadscale	1.08	1.22	0.94	1.92	1.42	0.47	0.61	0.95	1.00	2.08
Morn	1.00	1.83	0.83	4.00	0.75	0.67	0.50	1.00	0.67	2.25
Aft	1.33	0.83	0.75	1.08	2.33	0.25	0.25	0.75	0.67	0.75
Even	0.92	1.00	1.25	0.67	1.17	0.50	1.08	1.08	1.67	3.25
Gr/Exan	2.00	1.97	1.25	1.06	1.02	0.83	0.81	2.07	1.32	1.71
Morn	2.83	2.26	1.55	1.22	1.33	1.01	0.79	1.64	0.83	1.49
Aft	1.78	1.61	1.26	0.70	0.51	0.63	0.66	0.97	0.62	0.87
Even	1.38	2.04	0.93	1.25	1.22	0.83	1.00	3.59	2.51	2.77
Mosaic	1.78	1.30	1.22	1.11	0.41	0.93	2.18	1.94	1.22	1.45
Morn	1.61	2.00	1.11	1.22	0.33	1.00	0.61	2.39	0.72	1.78
Aft	2.11	0.67	0.89	0.89	0.22	0.28	0.28	1.00	1.33	1.22
Even	1.61	1.22	1.67	1.22	0.67	1.50	5.67	2.44	1.61	1.33

Table 11. Species means by habitat (agriculture, sagebrush, shadscale, grass/exotic annuals, shrub mosaic) and diurnal period (morning, afternoon, evening) within habitats for northern harriers over the entire study period, April 1991 - July 1994. Interaction and habitat terms are *P*-values where $P \leq 0.05$ is the accepted significant level (*).

	Breeding				Dry			Winter		
	1991	1992	1993	1994	1991	1992	1993	1991	1992	1993
Interaction *P*-value	0.003*	0.002*	0.08	0.30	0.18	0.002*	0.045*	0.0004*	0.001*	0.017*
Habitat *P*-value			0.00007*	0.09	0.06					
Agric	0.73	0.59	0.78	0.37	0.22	0.16	0.12	0.27	0.22	0.14
Morn	0.82	0.71	0.82	0.29	0.11	0.24	0.06	0.25	0.35	0.29
Aft	0.59	0.59	0.59	0.41	0.28	0.06	0.24	0.19	0.18	0.06
Even	0.77	0.47	0.94	0.41	0.28	0.18	0.06	0.38	0.12	0.06
Sagebrush	0.55	0.36	0.53	0.23	0.08	0.05	0.07	0.31	0.19	0.14
Morn	0.73	0.55	0.64	0.26	0.15	0.09	0.08	0.27	0.17	0.11
Aft	0.28	0.30	0.41	0.20	0.06	0.03	0.03	0.19	0.12	0.14
Even	0.63	0.23	0.55	0.24	0.03	0.03	0.11	0.45	0.27	0.18
Shadscale	0.03	0.11	0.11	0.17	0.06	0.03	0.03	0.00	0.08	0.11
Morn	0.00	0.25	0.08	0.25	0.17	0.00	0.00	0.00	0.17	0.17
Aft	0.00	0.00	0.25	0.08	0.00	0.08	0.00	0.00	0.00	0.17
Even	0.08	0.08	0.00	0.17	0.00	0.00	0.08	0.00	0.08	0.00
Gr/Exan	0.26	0.14	0.27	0.15	0.07	0.04	0.07	0.16	0.05	0.01
Morn	0.25	0.26	0.33	0.17	0.11	0.03	0.12	0.20	0.03	0.07
Aft	0.21	0.04	0.25	0.12	0.06	0.01	0.04	0.12	0.03	0.09
Even	0.33	0.11	0.24	0.17	0.08	0.07	0.04	0.16	0.11	0.06
Mosaic	0.30	0.22	0.32	0.11	0.02	0.04	0.00	0.04	0.11	0.04
Morn	0.28	0.22	0.22	0.11	0.06	0.00	0.00	0.00	0.06	0.06
Aft	0.22	0.06	0.17	0.11	0.00	0.00	0.00	0.06	0.28	0.06
Even	0.39	0.39	0.56	0.11	0.00	0.11	0.00	0.06	0.00	0.00

Table 12. Species means by habitat (agriculture, sagebrush, shadscale, grass/exotic annuals, shrub mosaic) and diurnal period (morning, afternoon, evening) within habitats for prairie falcons over the entire study period, April 1991 - July 1994. Interaction and habitat terms are *P*-values where $P \leq 0.05$ is the accepted significant level (*).

	Breeding				Dry			Winter		
	1991	1992	1993	1994	1991	1992	1993	1991	1992	1993
Interaction										
P-value	0.11	0.08	0.01*	0.09	0.75	0.93	0.47	0.006*	0.018*	0.87
Habitat										
P-value	0.018*	0.09		0.27	0.83	0.93	0.37			0.45
Agric	0.18	0.06	0.14	0.14	0.02	0.04	0.00	0.06	0.24	0.10
Morn	0.18	0.06	0.18	0.06	0.00	0.06	0.00	0.13	0.24	0.06
Aft	0.12	0.06	0.24	0.06	0.06	0.00	0.00	0.06	0.35	0.12
Even	0.24	0.06	0.00	0.29	0.00	0.06	0.00	0.00	0.12	0.12
Sagebrush	0.37	0.19	0.24	0.14	0.04	0.03	0.04	0.15	0.08	0.05
Morn	0.24	0.15	0.35	0.15	0.06	0.02	0.05	0.15	0.08	0.03
Aft	0.36	0.23	0.20	0.18	0.03	0.05	0.05	0.19	0.09	0.08
Even	0.51	0.18	0.18	0.09	0.02	0.02	0.02	0.10	0.06	0.05
Shadscale	0.33	0.11	0.25	0.03	0.06	0.06	0.00	0.17	0.06	0.03
Morn	0.25	0.08	0.33	0.00	0.08	0.08	0.00	0.42	0.00	0.00
Aft	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.08
Even	0.50	0.25	0.42	0.08	0.08	0.08	0.00	0.08	0.00	0.00
Gr/Exan	0.20	0.09	0.14	0.09	0.06	0.03	0.02	0.06	0.07	0.06
Morn	0.20	0.13	0.11	0.08	0.08	0.03	0.03	0.08	0.04	0.04
Aft	0.13	0.05	0.13	0.11	0.08	0.01	0.03	0.01	0.07	0.04
Even	0.28	0.08	0.18	0.09	0.00	0.04	0.00	0.08	0.09	0.09
Mosaic	0.37	0.15	0.33	0.17	0.04	0.04	0.02	0.06	0.09	0.09
Morn	0.56	0.11	0.33	0.22	0.06	0.11	0.00	0.00	0.06	0.11
Aft	0.22	0.11	0.22	0.00	0.00	0.00	0.06	0.00	0.06	0.11
Even	0.33	0.22	0.44	0.28	0.06	0.00	0.00	0.17	0.17	0.06

Table 13. Species means by habitat (agriculture, sagebrush, shadscale, grass/exotic annuals, shrub mosaic) and diurnal period (morning, afternoon, evening) within habitats for red-tailed hawks over the entire study period, April 1991 - July 1994. Interaction and habitat terms are *P*-values where $P \leq 0.05$ is the accepted significant level (*).

	Breeding				Dry			Winter		
	1991	1992	1993	1994	1991	1992	1993	1991	1992	1993
Interaction *P*-value	0.06	0.006*	0.09	0.10	0.81	0.94	0.047*	0.60	0.59	0.53
Habitat *P*-value	0.021*		0.005*	0.007*	0.59	0.55		0.68	0.38	0.67
Agric	0.16	0.16	0.24	0.18	0.15	0.12	0.08	0.06	0.04	0.10
Morn	0.18	0.18	0.00	0.12	0.11	0.12	0.06	0.06	0.00	0.06
Aft	0.24	0.06	0.53	0.35	0.06	0.24	0.18	0.13	0.06	0.12
Even	0.06	0.24	0.18	0.06	0.28	0.00	0.00	0.00	0.06	0.12
Sagebrush	0.22	0.15	0.24	0.17	0.04	0.03	0.04	0.06	0.02	0.03
Morn	0.21	0.06	0.09	0.14	0.05	0.05	0.02	0.05	0.02	0.02
Aft	0.15	0.24	0.44	0.23	0.05	0.03	0.05	0.02	0.05	0.06
Even	0.30	0.14	0.20	0.14	0.03	0.02	0.05	0.13	0.00	0.02
Shadscale	0.08	0.06	0.08	0.03	0.00	0.03	0.00	0.17	0.00	0.00
Morn	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00
Aft	0.00	0.08	0.17	0.00	0.00	0.08	0.00	0.17	0.00	0.00
Even	0.17	0.08	0.08	0.08	0.00	0.00	0.00	0.08	0.00	0.00
Gr/Exan	0.17	0.03	0.14	0.07	0.06	0.04	0.02	0.06	0.01	0.02
Morn	0.17	0.00	0.09	0.08	0.06	0.03	0.03	0.01	0.01	0.03
Aft	0.22	0.08	0.22	0.05	0.11	0.08	0.01	0.04	0.01	0.00
Even	0.11	0.01	0.09	0.07	0.01	0.01	0.03	0.12	0.01	0.03
Mosaic	0.02	0.17	0.30	0.07	0.06	0.02	0.02	0.07	0.00	0.06
Morn	0.00	0.17	0.22	0.06	0.06	0.00	0.00	0.00	0.00	0.06
Aft	0.00	0.22	0.28	0.11	0.11	0.06	0.00	0.11	0.00	0.11
Even	0.06	0.11	0.39	0.06	0.00	0.00	0.06	0.11	0.00	0.00

Table 14. Species means by habitat (agriculture, sagebrush, shadscale, grass/exotic annuals, shrub mosaic) and diurnal period (morning, afternoon, evening) within habitats for golden eagles over the entire study period, April 1991 - July 1994. Interaction and habitat terms are *P*-values where $P \leq 0.05$ is the accepted significant level (*).

	Breeding				Dry			Winter		
	1991	1992	1993	1994	1991	1992	1993	1991	1992	1993
Interaction *P*-value	0.01*	0.0005*	0.005*	0.003*	0.13*	0.51	0.28	0.09	0.14	0.13
Habitat *P*-value						0.21	0.06	0.002*	0.006*	0.06
Agric	0.04	0.06	0.14	0.06	0.07	0.06	0.08	0.06	0.18	0.10
Morn	0.06	0.06	0.18	0.12	0.00	0.00	0.06	0.00	0.06	0.06
Aft	0.06	0.12	0.12	0.06	0.22	0.12	0.06	0.13	0.24	0.12
Even	0.00	0.00	0.12	0.00	0.00	0.06	0.12	0.06	0.24	0.12
Sagebrush	0.23	0.18	0.19	0.19	0.04	0.10	0.08	0.16	0.10	0.23
Morn	0.10	0.20	0.21	0.17	0.03	0.06	0.06	0.08	0.05	0.21
Aft	0.28	0.26	0.18	0.23	0.08	0.11	0.12	0.19	0.17	0.27
Even	0.31	0.08	0.18	0.17	0.02	0.12	0.06	0.21	0.09	0.20
Shadscale	0.11	0.00	0.00	0.03	0.00	0.08	0.06	0.06	0.03	0.14
Morn	0.17	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.08	0.17
Aft	0.08	0.00	0.00	0.08	0.00	0.08	0.08	0.08	0.00	0.17
Even	0.08	0.00	0.00	0.00	0.00	0.17	0.00	0.08	0.00	0.08
Gr/Exan	0.10	0.04	0.08	0.05	0.00	0.03	0.01	0.10	0.07	0.08
Morn	0.05	0.04	0.01	0.05	0.00	0.01	0.01	0.07	0.07	0.05
Aft	0.13	0.07	0.08	0.05	0.00	0.00	0.03	0.09	0.09	0.05
Even	0.13	0.00	0.13	0.04	0.00	0.07	0.00	0.13	0.04	0.13
Mosaic	0.13	0.06	0.15	0.17	0.13	0.07	0.07	0.35	0.26	0.17
Morn	0.11	0.11	0.22	0.28	0.11	0.11	0.00	0.22	0.28	0.33
Aft	0.06	0.00	0.00	0.00	0.11	0.06	0.17	0.39	0.22	0.11
Even	0.22	0.06	0.22	0.22	0.17	0.06	0.06	0.44	0.28	0.06

Table 15. Species means by habitat (agriculture, sagebrush, shadscale, grass/exotic annuals, shrub mosaic) and diurnal period (morning, afternoon, evening) within habitats for Swainson's hawks over the entire study period, April 1991 - July 1994. Interaction and habitat terms are *P*-values where $P \leq 0.05$ is the accepted significant level (*).

	Breeding				Dry			Winter		
	1991	1992	1993	1994	1991	1992	1993	1991	1992	1993
Interaction										
P-value	0.28	0.51	0.045*	0.07	0.44	----	0.70	0.34	----	----
Habitat										
P-value	0.18	0.32		0.05*	0.12	----	0.40	0.25	----	----
Agric	0.24	0.06	0.18	0.22	0.09	----	0.02	0.02	----	----
Morn	0.24	0.18	0.00	0.12	0.00	----	0.00	0.00	----	----
Aft	0.24	0.00	0.24	0.41	0.17	----	0.06	0.00	----	----
Even	0.24	0.00	0.29	0.12	0.11	----	0.00	0.06	----	----
Sagebrush	0.15	0.07	0.18	0.08	0.16	----	0.01	0.00	----	----
Morn	0.08	0.11	0.27	0.08	0.48	----	0.01	0.00	----	----
Aft	0.16	0.06	0.17	0.14	0.02	----	0.00	0.00	----	----
Even	0.22	0.03	0.09	0.02	0.00	----	0.00	0.00	----	----
Shadscale	0.03	0.03	0.06	0.06	0.03	----	0.00	0.00	----	----
Morn	0.00	0.08	0.00	0.08	0.00	----	0.00	0.00	----	----
Aft	0.08	0.00	0.17	0.00	0.08	----	0.00	0.00	----	----
Even	0.00	0.00	0.00	0.08	0.00	----	0.00	0.00	----	----
Gr/Exan	0.16	0.04	0.10	0.03	0.01	----	0.01	0.02	----	----
Morn	0.13	0.03	0.07	0.04	0.01	----	0.01	0.03	----	----
Aft	0.03	0.07	0.01	0.00	0.00	----	0.03	0.00	----	----
Even	0.33	0.04	0.22	0.05	0.00	----	0.00	0.04	----	----
Mosaic	0.04	0.02	0.06	0.02	0.02	----	0.02	0.00	----	----
Morn	0.06	0.00	0.17	0.06	0.00	----	0.00	0.00	----	----
Aft	0.06	0.06	0.00	0.00	0.06	----	0.06	0.00	----	----
Even	0.00	0.00	0.00	0.00	0.00	----	0.00	0.00	----	----

Table 16. Species means by habitat (agriculture, sagebrush, shadscale, grass/exotic annuals, shrub mosaic) and diurnal period (morning, afternoon, evening) within habitats for ferruginous hawks over the entire study period, April 1991 - July 1994. Interaction and habitat terms are *P*-values where $P \leq 0.05$ is the accepted significant level (*).

	Breeding				Dry			Winter		
	1991	1992	1993	1994	1991	1992	1993	1991	1992	1993
Interaction *P*-value	0.68	0.24	0.07	0.25	0.66	0.47	0.13	1.00	----	1.00
Habitat *P*-value	0.91	0.62	0.007*	0.21	0.52	0.36	0.25	0.48	----	1.00
Agric	0.04	0.08	0.04	0.02	0.00	0.00	0.00	0.00	----	0.00
Morn	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	----	0.00
Aft	0.06	0.12	0.06	0.06	0.00	0.00	0.00	0.00	----	0.00
Even	0.06	0.12	0.00	0.00	0.00	0.00	0.00	0.00	----	0.00
Sagebrush	0.08	0.04	0.04	0.05	0.01	0.01	0.00	0.02	----	0.01
Morn	0.05	0.00	0.03	0.02	0.02	0.01	0.00	0.02	----	0.00
Aft	0.08	0.09	0.03	0.06	0.00	0.00	0.00	0.02	----	0.00
Even	0.10	0.02	0.05	0.06	0.00	0.00	0.00	0.02	----	0.01
Shadscale	0.08	0.06	0.03	0.00	0.03	0.00	0.03	0.00	----	0.03
Morn	0.17	0.17	0.08	0.00	0.08	0.00	0.00	0.00	----	0.00
Aft	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	----	0.08
Even	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	----	0.00
Gr/Exan	0.10	0.08	0.11	0.06	0.01	0.01	0.01	0.02	----	0.00
Morn	0.11	0.07	0.12	0.05	0.03	0.01	0.04	0.03	----	0.01
Aft	0.08	0.08	0.11	0.05	0.01	0.01	0.00	0.00	----	0.00
Even	0.11	0.09	0.11	0.08	0.00	0.00	0.00	0.03	----	0.00
Mosaic	0.11	0.04	0.09	0.00	0.00	0.00	0.00	0.02	----	0.00
Morn	0.06	0.06	0.11	0.00	0.00	0.00	0.00	0.06	----	0.00
Aft	0.28	0.06	0.06	0.00	0.00	0.00	0.00	0.00	----	0.00
Even	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	----	0.00

Table 17. Species means by habitat (agriculture, sagebrush, shadscale, grass/exotic annuals, shrub mosaic) and diurnal period (morning, afternoon, evening) within habitats for rough-legged hawks over the entire study period, April 1991 - July 1994. Interaction and habitat terms are *P*-values where $P \leq 0.05$ is the accepted significant level (*).

	Breeding				Dry			Winter		
	1991	1992	1993	1994	1991	1992	1993	1991	1992	1993
Interaction										
P-value	0.67	0.06	0.45	0.12	1.00	0.03*	0.004*	0.69	0.31	0.22
Habitat										
P-value	0.17	0.23	0.36	0.26	0.75			0.77	0.06	0.34
Agric	0.02	0.26	0.14	0.02	0.00	0.20	0.06	0.27	0.50	0.12
Morn	0.00	0.47	0.24	0.06	0.00	0.24	0.18	0.19	0.65	0.00
Aft	0.06	0.29	0.06	0.00	0.00	0.12	0.00	0.44	0.35	0.29
Even	0.00	0.00	0.12	0.00	0.00	0.24	0.00	0.19	0.47	0.06
Sagebrush	0.05	0.26	0.09	0.05	0.00	0.04	0.01	0.15	0.18	0.07
Morn	0.02	0.33	0.05	0.02	0.00	0.03	0.00	0.18	0.14	0.08
Aft	0.05	0.32	0.15	0.09	0.00	0.08	0.03	0.08	0.24	0.03
Even	0.09	0.14	0.08	0.05	0.00	0.02	0.00	0.19	0.15	0.09
Shadscale	0.08	0.17	0.14	0.00	0.03	0.03	0.03	0.08	0.17	0.03
Morn	0.08	0.00	0.08	0.00	0.00	0.08	0.00	0.17	0.08	0.00
Aft	0.08	0.42	0.17	0.00	0.08	0.00	0.00	0.00	0.08	0.08
Even	0.08	0.08	0.17	0.00	0.00	0.00	0.08	0.08	0.33	0.00
Gr/Exan	0.03	0.18	0.18	0.03	0.01	0.04	0.01	0.17	0.15	0.12
Morn	0.00	0.21	0.08	0.01	0.01	0.03	0.01	0.11	0.18	0.15
Aft	0.05	0.18	0.22	0.07	0.00	0.07	0.00	0.16	0.15	0.12
Even	0.30	0.15	0.24	0.00	0.01	0.03	0.01	0.24	0.12	0.11
Mosaic	0.00	0.17	0.06	0.04	0.02	0.04	0.00	0.17	0.20	0.07
Morn	0.00	0.22	0.06	0.11	0.06	0.00	0.00	0.22	0.17	0.06
Aft	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.17	0.33	0.00
Even	0.00	0.28	0.11	0.00	0.00	0.00	0.00	0.11	0.11	0.17

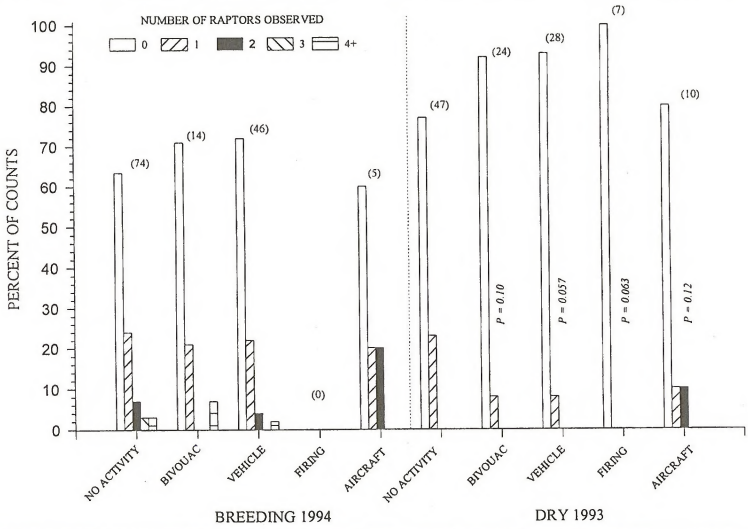

Fig. 4. **The percent of zero, 1, 2, 3, and 4 or more raptors counted on OTA sites with no military activity and sites where bivouacs, vehicles, firing, or aircraft were recorded within 3 km of site center and within a 3-hr period before or during the observation period for the 1994 breeding season and the 1993 dry season.**

recorded in the morning and evening than in the afternoon. Breeding 1992 was the exception with a gradual decline in numbers from morning to evening in both agriculture and sagebrush sites. In the dry seasons, diurnal patterns in the other habitats were difficult to assess because harriers were so strongly associated with agriculture sites. Diurnal use patterns at agriculture sites varied each dry season. In the winter, harriers tended to associate with the agriculture sites most strongly in the mornings and the sagebrush sites in the evenings. Harrier numbers were too low and inconsistent in the other habitats to discern a pattern.

Prairie Falcon.-- Prairie falcons showed significant interactions between habitat and time of day in breeding 1993, winter 1991, and winter 1992 (Table 12). Although not always significant, prairie falcons tended to associate most consistently with the various shrub habitats and avoid grass and agriculture sites in most seasons. However, in dry 1992 and breeding 1994, they did not avoid agriculture and in winter 1992 and 1993 were strongly associated with agriculture. Diurnal use patterns were not consistent in any habitat or season.

Red-Tailed Hawk.-- Red-tailed hawks showed a significant interaction between habitat and time of day in breeding 1992 and dry 1993 (Table 13). Their habitat associations in the breeding seasons were always significant. Despite low numbers, the same habitat association trends were apparent in all the non-breeding seasons. Red-tailed hawks consistently avoided shadscale and, depending on the year, avoided shrub mosaic (breeding 1991) and grass/exotic annuals (breeding 1992). They were most consistently associated with sagebrush and agriculture sites during the breeding season and with just agriculture sites in the dry seasons. Red-tailed hawks did not associate with any particular habitat in the winter seasons. In general, red-tailed hawks were seen most often in the afternoon time period. The significant interaction in breeding 1992 and dry 1993 was produced by different diurnal patterns at agriculture sites as compared to the other habitats. Red-tailed hawk counts were lowest in the afternoons at agriculture sites and highest in the afternoon in the other habitats. In dry 1993, red-tailed hawks were seen most often in the afternoon in agriculture and in the evenings in shrub mosaic.

Golden Eagle. -- Golden eagles consistently showed a significant interaction between habitat and time of day during the breeding seasons and also in dry 1991 (Table 14). Golden eagles were strongly and consistently associated with sagebrush and shrub mosaic sites in all seasons except dry 1992, when their numbers were extremely low. In most breeding seasons they avoided agriculture sites; however, in the non-breeding seasons they occurred in them equally with other habitats. Golden eagles' strongest association with agriculture sites was in dry 1992, winter 1992 and breeding 1993, the 3 seasons immediately following the spring/summer drought of 1992. They avoided shadscale and/or grass/exotic annual sites in dry 1991 and 1993, winter 1992 and 1993, and breeding 1992 and 1993. Golden eagles tended to use sagebrush and shrub mosaic habitats differently throughout the day. Regardless of season, they were seen at the sagebrush sites most often in the afternoon and at shrub mosaic sites in the mornings and evenings. During winter, eagles used agriculture sites most often in the afternoons and evenings, but in the breeding season morning association was most common.

Swainson's Hawk.-- Swainson's hawks were present in sufficient numbers for analysis in the study area during the breeding seasons only. Breeding 1993 had the only significant interaction term between habitat and time of day (Table 15). Swainson's hawks were consistently associated with agriculture and sagebrush sites, but the association was significant only in breeding 1993 and 1994. Swainson's hawks were very inconsistent in their association with different habitats at different times of day across years. In breeding 1991 they were associated with agriculture sites consistently throughout the day. In 1992 they were present only in the morning, tending to switch to sagebrush and grass sites in the afternoon and evening. In breeding 1993, they were present at sagebrush and shrub mosaic sites more commonly in the morning, agriculture in the afternoon and evening, shadscale exclusively in the afternoon, and grass in the evening. In breeding 1994, they associated with sagebrush and agriculture most commonly in the afternoon and the other habitats in morning and/or evening.

Ferruginous Hawk.-- Ferruginous hawks, like Swainson's hawks, were present mainly in the breeding seasons. They showed no significant interactions between habitat and time of day (Table 16). They associated most commonly with grass/exotic annual and shrub mosaic sites, but the relationship was significant only in breeding 1993. Ferruginous hawks occurred at grass/exotic annual sites consistently throughout the day, only in the mornings in shadscale, and most often in the afternoon in the other habitats. The species' abundance was too low and sporadic in the non-breeding seasons to show any pattern in diurnal use and habitat association except a preference for grass/exotic annual areas.

Rough-legged Hawk.-- Rough-legged hawks were mainly present on the study area in the winter and early breeding seasons. The only significant interactions between habitat and time of day were in dry 1992 and 1993, when their numbers were very low (Table 17). Their habitat associations in the breeding seasons were very inconsistent. In breeding 1992 they were most commonly seen at sagebrush and agriculture sites; in breeding 1993 they occurred across all habitats equally; and in 1994 their numbers were too low to compare. In the winter and dry seasons, they were most numerous near agriculture and evenly distributed across the other habitats. We could discern no consistent pattern in diurnal use in any season or habitat.

Habitat Use vs. Availability.-- The MRPP analyses of percent cover of different vegetation types at sites where ravens and raptor species were recorded vs. what was generally available in the ISA yielded few significant results. In every season ravens, northern harriers, prairie falcons, red-tailed hawks, and Swainson's hawks associated with a range of sites whose habitat composition reflected what was generally available to them in the ISA. Ferruginous hawks were recorded at sites with significantly different habitat compositions than were generally available in breeding 1993 (d = 45.99, P =0.025) and in winter 1993 (d = 24.77, P = 0.05). In both seasons, ferruginous hawks occurred at sites with lower coverage of sagebrush and/or greater coverage of grass/exotic annuals. Rough-legged hawks in breeding 1993 were recorded at sites with fewer sagebrush and/or greater amounts of grass/exotic annuals (d = 48.60, P = 0.043). In breeding 1994, golden eagles associated with sites with greater amounts of sagebrush (d = 45.66, P = 0.007). The rock, fence, and power line analyses yielded a few more significant results than the vegetation profile analyses, but were still sporadic and inconsistent except, perhaps, for ferruginous hawks. In the 1992 breeding season, prairie falcons displayed an increased association with rocks and an avoidance of power lines (d = 0.97, P = 0.05), whereas golden eagles avoided fences as well as power lines (d = 0.93, P = 0.03). Ferruginous hawks avoided sites with power lines and were recorded more often at sites with rocks in 3 seasons: dry 1991 (d = 0.40, P = 0.014), dry 1993 (d = 0.50, P = 0.04) and breeding 1994 (d = 0.88, P = 0.04). Rough-legged hawks were recorded more often at sites with rocks than were generally available and avoided sites with fences and power lines in the breeding 1991 season only (d = 0.75, P = 0.006).

Agricultural Lands.-- Of the 119 non-OTA sites, 48 were designated as near-ag sites. The corrections to the agriculture map in resulted in a number of changes in the significant results reported last year for all species except ferruginous hawks (Strickler and Watson 1993).

Ravens were significantly more abundant at near-ag sites in ≥1 period of every season except winter 1993 (Table 18). In breeding 1991, they were significantly more abundant at near-ag sites during morning (d = 3.57, P = 0.018) and afternoon (d = 3.43, P = 0.00002) counts. Ravens were most numerous at near-ag sites in the afternoon, but at non-ag sites they were recorded in their highest numbers in the morning. In breeding 1992, ravens were most numerous at the near-ag sites in the morning and evening and, again, were most common at non-ag sites in the morning. However, ravens were still significantly more abundant in the mornings at near-ag sites than at non-ag sites (d = 4.09, P = 0.002). During all dry seasons, we counted significantly more ravens at near-ag sites than non-ag sites in all periods except for evenings in dry 1993 (1991: morning - d = 2.35, P = 0.00001; afternoon - d = 2.39, P = 0.7×10^{-6}; evening - d = 4.53, P = 0.00008; 1992: morning - d = 2.24, P = 0.2×10^{-6}; afternoon - d = 2.07, P = 0.9×10^{-8}; evening - d = 2.55, P = 0.3×10^{-6}; 1993: morning - d = 1.58, P = 0.004; afternoon - d = 1.69. P = 0.8×10^{-6}). Ravens were most numerous at near-ag sites in the

Table 18. Mean counts of common ravens at non-ag (>2 km from agriculture) and near-ag (≤2 km from agriculture) non-OTA sites in the Integration Study Area (ISA) during 10 seasons, from April 1991 to July 1994. (M = morning; A = afternoon; E = evening).

	ALL NON-OTA SITES			NON-AG SITES				NEAR-AG SITES			
Season	M	A	E	Total	M	A	E	Total	M	A	E
Breeding 1991											
N	120	120	115	217	74	74	69	138	46	46	46
Mean	2.90	2.78	2.09	1.90	2.35[a]	1.55[f]	1.78	3.70	3.78[e]	4.76[f]	2.54
SD	4.44	4.35	3.09	2.71	3.26	1.90	2.76	5.32	5.78	6.14	3.51
Dry 1991											
N	120	119	120	221	74	73	74	138	46	46	46
Mean	1.66	1.55	2.64	0.58	0.78[a]	0.42[f]	0.53[g]	4.14	3.06[e]	3.33[f]	6.04[g]
SD	3.09	4.00	9.54	1.35	1.62	1.13	1.24	9.54	4.21	5.90	14.80
Winter 1991-92											
N	119	116	119	220	74	73	73	134	45	43	46
Mean	2.15	1.90	4.31	1.86[a]	1.49	1.19	2.92	4.32[a]	3.24	3.09	6.52
SD	2.87	4.27	10.18	3.82	1.95	2.16	5.84	9.50	3.71	6.29	14.46
Breeding 1992											
N	120	120	120	222	74	74	74	138	46	46	46
Mean	3.09	2.19	2.57	1.83	2.26[a]	1.77	1.46	3.88	4.43[a]	2.87	4.35
SD	5.89	3.55	6.59	3.43	4.41	3.14	2.45	7.59	7.58	4.05	9.99
Dry 1992											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	1.79	1.52	1.77	0.63	0.86[a]	0.45[f]	0.58[g]	3.38	3.26[e]	3.22[f]	3.67[g]
SD	2.87	3.07	3.74	1.36	1.66	0.99	1.33	4.43	3.68	4.28	5.27
Winter 1992-93											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	1.55	1.24	3.82	1.26	0.88[a]	0.95	1.97[g]	3.70	2.61[e]	1.72	6.76[g]
SD	4.53	2.46	9.69	3.66	1.41	1.43	5.98	9.07	6.99	3.50	13.20
Breeding 1993											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	2.16	1.96	2.25	1.66[a]	1.34	1.38	2.26	2.86[e]	3.46	2.87	2.24
SD	3.79	3.16	6.65	5.03	1.71	2.31	8.23	4.25	5.49	4.04	2.78
Dry 1993											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.98	1.08	2.96	1.26	0.81[a]	0.37[f]	2.60	2.33	1.26[e]	2.22[f]	3.52
SD	2.80	2.64	9.75	6.68	3.29	1.26	10.95	5.00	1.78	3.69	7.53
Winter 1993-94											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	1.77	1.20	2.36	1.57	1.23	1.04	2.44	2.11	2.63	1.46	2.24
SD	2.39	1.64	5.28	3.78	1.94	1.40	6.04	2.98	2.77	1.96	3.84
Breeding 1994											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	1.74	1.22	1.36	1.01[a]	1.08	0.79	1.15	2.12[a]	2.78	1.89	1.70
SD	4.30	1.58	2.01	1.73	1.78	1.30	2.03	4.01	6.44	1.75	1.96

[a] Non-ag/near-ag comparison: $P \leq 0.05$
[b] Morning/afternoon comparison: $P \leq 0.017$
[c] Morning/evening comparison: $P \leq 0.017$
[d] Afternoon/evening comparison: $P \leq 0.017$
[e] Non-ag/near-ag comparison in morning period: $P \leq 0.017$
[f] Non-ag/near-ag comparison in afternoon period: $P \leq 0.017$
[g] Non-ag/near-ag comparison in evening period: $P \leq 0.017$

evenings and at non-ag sites in the mornings, except in dry 1993. Ravens were more abundant at near-ag sites in the 1991 winter season (d = 2.66, P = 0.0017). In winter 1992, there were significantly more ravens at near-ag sites in the mornings (d = 2.32, P = 0.013) and in the evenings (d = 6.17, P = 0.003). Ravens were most common in the evenings at both near-ag and non-ag sites.

We recorded significantly more northern harriers at near-ag sites during the 1993 breeding season (d = 0.46, P = 0.0072) and during morning (d = 0.36, P = 0.016) and afternoon (d = 0.30, P = 0.003) counts in breeding 1994 (Table 19). Also, they were seen significantly more often at near-ag sites in the 1991 dry season (d = 0.18, P = 0.016) and during the morning in dry 1992 (d = 0.14, P = 0.012).

Prairie falcons, not being strongly associated with agriculture, showed just 2 significant interactions between agriculture and time of day; both were winter seasons (1991 - d = 2.05, P = 0.021; 1992 - d = 2.03, P = 0.011). We observed more falcons at near-ag sites in the mornings in both seasons, (1991 - d = 0.24, P = 0.026; 1992 - d = 0.18, P = 0.039), and in the afternoons during 1992 (d = 0.22, P = 0.020) (Table 20). We counted more falcons at non-ag sites in the evenings during 1991 (d = 0.15, P = 0.023). However, due to the Bonferroni adjustments, none of these differences were significant.

Red-tailed hawks were significantly more abundant at near-ag sites during breeding 1994 (d = 0.20, P = 0.012), in the mornings in dry 1991 (d = 0.16, P = 0.005), and in the afternoons in dry 1993 (d = 0.11, P = 0.007) (Table 21).

Golden eagle results were affected by the changes in the agriculture map in only 1 season and time period. We recorded significantly more golden eagles at the near-ag sites during afternoon in breeding 1993 (d = 0.19, P = 0.0002) (Table 22). The number of significant diurnal differences remained few with afternoon counts of golden eagles higher than evening counts in breeding 1992 (d = 0.50 , P = 0.0025), and mornings counts in winter 1991 (d = 1.18, P = 0.015).

Swainson's hawks were significantly more abundant at near-ag sites in the afternoon in breeding 1993 (d = 0.26, P = 0.006) and breeding 1994 (d = 0.21, P = 0.0006) (Table 23). They were also significantly more abundant at near-ag sites in dry 1991 (d = 0.22, P = 0.019).

Ferruginous hawk numbers did not differ significantly between the near-ag and non-ag sites in any season (Table 24). In general, ferruginous hawks were more abundant in the non-ag areas.

Rough-legged hawks were more abundant at near-ag sites in winter 1992 (d = 0.30, P = 0.0038), during morning (d = 0.11, P = 0.006) and evening (d = 0.11, P = 0.007) in dry 1992, and in the mornings only in dry 1993 (d = 0.06, P = 0.006) (Table 25).

DISCUSSION

We recorded the lowest counts of ravens and all common raptor species during the 1993 dry, 1993-94 winter (except golden eagles), and 1994 breeding seasons than at any other time in the study. Analyses of bird abundance and habitat association in the last 3 seasons also yielded minimal numbers of significant interactions and differences when compared to previous seasons. The lower number of statistical differences may reflect the loss of statistical power caused by lower numbers of birds and more zero counts. We may be dealing with the minimum numbers of birds needed to retain any statistical power for the questions we are asking. On the other hand, our results may reflect very real biological information. For example, during times of low raptor numbers, birds may be less restricted in their movements by the presence of other raptors. Alternatively, when prey numbers are low throughout the ISA, including in agricultural areas, birds may be forced to forage over larger areas, and thus, are recorded in a wider range of habitats. Townsend's ground squirrel numbers were very low in the 1994 breeding season as predicted by Van Horne et al. (1993). Other prey species, such as smaller rodents which are less seasonal in their presence in the ISA, also may have been in low numbers, consequently supporting fewer raptors and forcing those raptors to use larger foraging areas, especially during the non-breeding seasons.

Table 19. Mean counts of northern harriers at non-ag (>2 km from agriculture) and near-ag (≤2 km from agriculture) non-OTA sites in the Integration Study Area (ISA) during 10 seasons, from April 1991 to July 1994. (M = morning; A = afternoon; E = evening).

	ALL NON-OTA SITES			NON-AG SITES				NEAR-AG SITES			
Season	M	A	E	Total	M	A	E	Total	M	A	E
Breeding 1991											
N	120	120	115	217	74	74	69	138	46	46	46
Mean	0.45	0.31	0.50	0.37	0.39	0.28	0.45	0.49	0.54	0.35	0.59
SD	0.70	0.56	0.81	0.68	0.66	0.54	0.81	0.73	0.75	0.60	0.80
Dry 1991											
N	120	119	120	221	74	73	74	138	46	46	46
Mean	0.17	0.08	0.09	0.07[a]	0.14	0.04	0.04	0.18[a]	0.22	0.15	0.17
SD	0.40	0.36	0.32	0.26	0.34	0.20	0.20	0.47	0.47	0.51	0.44
Winter 1991-92											
N	119	116	119	220	74	73	73	134	45	43	46
Mean	0.23	0.14	0.26	0.13	0.18	0.08	0.14	0.34	0.31	0.23	0.46
SD	0.57	0.41	0.56	0.39	0.51	0.28	0.35	0.67	0.67	0.57	0.75
Breeding 1992											
N	120	120	120	222	74	74	74	138	46	46	46
Mean	0.38	0.23	0.23	0.19	0.24	0.15	0.19	0.42	0.59	0.37	0.30
SD	0.77	0.59	0.58	0.48	0.49	0.43	0.52	0.84	1.05	0.77	0.66
Dry 1992											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.07	0.03	0.06	0.03	0.03[a]	0.03	0.04	0.09	0.15[a]	0.04	0.09
SD	0.27	0.18	0.24	0.18	0.16	0.16	0.20	0.29	0.36	0.21	0.29
Winter 1992-93											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.15	0.13	0.17	0.11	0.11	0.10	0.12	0.22	0.22	0.20	0.24
SD	0.42	0.49	0.48	0.41	0.36	0.41	0.47	0.52	0.51	0.58	0.48
Breeding 1993											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.52	0.35	0.40	0.33[a]	0.40	0.27	0.32	0.58[a]	0.72	0.48	0.54
SD	0.80	0.56	0.74	0.62	0.70	0.48	0.66	0.81	0.91	0.66	0.84
Dry 1993											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.06	0.07	0.08	0.05	0.07	0.05	0.04	0.09	0.04	0.09	0.13
SD	0.24	0.25	0.27	0.23	0.25	0.23	0.20	0.28	0.21	0.28	0.34
Winter 1993-94											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.10	0.08	0.09	0.07	0.07	0.10	0.05	0.12	0.15	0.06	0.15
SD	0.33	0.28	0.29	0.26	0.25	0.30	0.23	0.35	0.42	0.25	0.36
Breeding 1994											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.21	0.18	0.24	0.12	0.11[e]	0.08[f]	0.18	0.36	0.37[e]	0.35[f]	0.35
SD	0.55	0.45	0.65	0.40	0.38	0.28	0.53	0.71	0.74	0.60	0.79

[a] Non-ag/near-ag comparison: $P \leq 0.05$
[b] Morning/afternoon comparison: $P \leq 0.017$
[c] Morning/evening comparison: $P \leq 0.017$
[d] Afternoon/evening comparison: $P \leq 0.017$
[e] Non-ag/near-ag comparison in morning period: $P \leq 0.017$
[f] Non-ag/near-ag comparison in afternoon period: $P \leq 0.017$
[g] Non-ag/near-ag comparison in evening period: $P \leq 0.017$

Table 20. Mean counts of prairie falcons at non-ag (>2 km from agriculture) and near-ag (≤2 km from agriculture) non-OTA sites in the Integration Study Area (ISA) during 10 seasons, from April 1991 to July 1994. (M = morning; A = afternoon; E = evening).

	ALL NON-OTA SITES			NON-AG SITES				NEAR-AG SITES			
Season	M	A	E	Total	M	A	E	Total	M	A	E
Breeding 1991											
N	120	120	115	217	74	74	69	138	46	46	46
Mean	0.24	0.22	0.37	0.30	0.26	0.26	0.39	0.24	0.22	0.15	0.35
SD	0.50	0.57	0.71	0.61	0.50	0.66	0.67	0.57	0.51	0.36	0.77
Dry 1991											
N	120	119	120	221	74	73	74	138	46	46	46
Mean	0.07	0.07	0.02	0.04	0.05	0.05	0.01	0.07	0.09	0.09	0.02
SD	0.28	0.31	0.13	0.22	0.23	0.28	0.12	0.30	0.35	0.35	0.15
Winter 1991-92											
N	119	116	119	220	74	73	73	134	45	43	46
Mean	0.15	0.09	0.08	0.10	0.08	0.08	0.12	0.12	0.27	0.09	0
SD	0.38	0.45	0.32	0.40	0.27	0.49	0.41	0.37	0.50	0.37	0
Breeding 1992											
N	120	120	120	222	74	74	74	138	46	46	46
Mean	0.11	0.10	0.13	0.13	0.14	0.07	0.18	0.09	0.07	0.15	0.04
SD	0.34	0.33	0.40	0.38	0.38	0.25	0.48	0.31	0.25	0.42	0.21
Dry 1992											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.06	0.03	0.06	0.03	0.07	0	0.01	0.07	0.04	0.09	0.07
SD	0.24	0.29	0.24	0.16	0.25	0	0.12	0.32	0.21	0.46	0.25
Winter 1992-93											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.10	0.13	0.09	0.08	0.05	0.07	0.11	0.15	0.17	0.22	0.07
SD	0.30	0.38	0.29	0.28	0.23	0.30	0.31	0.38	0.38	0.47	0.25
Breeding 1993											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.20	0.18	0.21	0.21	0.22	0.15	0.25	0.18	0.17	0.22	0.15
SD	0.46	0.46	0.42	0.44	0.45	0.40	0.46	0.47	0.49	0.55	0.36
Dry 1993											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.03	0.02	0.01	0.01	0.03	0.01	0	0.03	0.04	0.02	0.02
SD	0.18	0.13	0.09	0.12	0.16	0.11	0	0.17	0.21	0.15	0.15
Winter 1993-94											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.05	0.09	0.07	0.04	0.04	0.03	0.05	0.12	0.07	0.20	0.09
SD	0.22	0.34	0.28	0.20	0.20	0.16	0.23	0.38	0.25	0.50	0.35
Breeding 1994											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.12	0.10	0.18	0.11	0.11	0.07	0.15	0.17	0.13	0.15	0.22
SD	0.35	0.33	0.48	0.37	0.31	0.30	0.46	0.43	0.40	0.36	0.51

[a] Non-ag/near-ag comparison: $P \leq 0.05$
[b] Morning/afternoon comparison: $P \leq 0.017$
[c] Morning/evening comparison: $P \leq 0.017$
[d] Afternoon/evening comparison: $P \leq 0.017$
[e] Non-ag/near-ag comparison in morning period: $P \leq 0.017$
[f] Non-ag/near-ag comparison in afternoon period: $P \leq 0.017$
[g] Non-ag/near-ag comparison in evening period: $P \leq 0.017$

Table 21. Mean counts of red-tailed hawks at non-ag (>2 km from agriculture) and near-ag (≤2 km from agriculture) non-OTA sites in the Integration Study Area (ISA) during 10 seasons, from April 1991 to July 1994. (M = morning; A = afternoon; E = evening).

	ALL NON-OTA SITES			NON-AG SITES				NEAR-AG SITES			
Season	M	A	E	Total	M	A	E	Total	M	A	E
Breeding 1991											
N	120	120	115	217	74	74	69	138	46	46	46
Mean	0.20	0.23	0.19	0.17	0.16	0.19	0.16	0.26	0.26	0.28	0.24
SD	0.46	0.51	0.45	0.44	0.44	0.49	0.41	0.52	0.49	0.54	0.52
Dry 1991											
N	120	119	120	221	74	73	74	138	46	46	46
Mean	0.09	0.08	0.07	0.04	0.03[a]	0.08	0.01	0.14	0.20[a]	0.07	0.15
SD	0.37	0.26	0.48	0.20	0.16	0.28	0.12	0.56	0.54	0.25	0.76
Winter 1991-92											
N	119	116	119	220	74	73	73	134	45	43	46
Mean	0.06	0.09	0.11	0.08	0.05	0.08	0.11	0.09	0.07	0.09	0.11
SD	0.27	0.31	0.34	0.32	0.28	0.32	0.36	0.29	0.25	0.29	0.31
Breeding 1992											
N	120	120	120	222	74	74	74	138	46	46	46
Mean	0.08	0.18	0.13	0.10	0.05	0.14	0.11	0.18	0.13	0.26	0.15
SD	0.31	0.55	0.38	0.34	0.23	0.45	0.31	0.53	0.40	0.68	0.47
Dry 1992											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.06	0.08	0.02	0.03	0.03	0.04	0.01	0.09	0.11	0.13	0.02
SD	0.27	0.35	0.13	0.16	0.16	0.20	0.12	0.37	0.38	0.50	0.15
Winter 1992-93											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.02	0.04	0.02	0.02	0.01	0.04	0.01	0.03	0.02	0.04	0.02
SD	0.13	0.20	0.13	0.15	0.12	0.20	0.12	0.17	0.15	0.21	0.15
Breeding 1993											
N	119	119	119		219	73	73	73	138	46	46
46											
Mean	0.12[b]	0.36[b]	0.20	0.18	0.12	0.25	0.18	0.30	0.11	0.54	0.24
SD	0.32	0.71	0.44	0.43	0.33	0.52	0.42	0.64	0.31	0.91	0.48
Dry 1993											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.03	0.06	0.04	0.02	0.03	0.01[f]	0.03	0.08	0.04	0.13[f]	0.07
SD	0.18	0.24	0.20	0.15	0.16	0.11	0.16	0.27	0.21	0.34	0.25
Winter 1993-94											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.03	0.04	0.02	0.02	0.01	0.04	0.01	0.04	0.07	0.04	0.02
SD	0.18	0.20	0.13	0.15	0.12	0.20	0.12	0.20	0.25	0.21	0.15
Breeding 1994											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.13	0.17	0.11	0.09[g]	0.10	0.10	0.07	0.21[g]	0.17	0.28	0.17
SD	0.38	0.49	0.31	0.33	0.34	0.30	0.25	0.52	0.44	0.69	0.38

[a] Non-ag/near-ag comparison: $P \leq 0.05$
[b] Morning/afternoon comparison: $P \leq 0.017$
[c] Morning/evening comparison: $P \leq 0.017$
[d] Afternoon/evening comparison: $P \leq 0.017$
[e] Non-ag/near-ag comparison in morning period: $P \leq 0.017$
[f] Non-ag/near-ag comparison in afternoon period: $P \leq 0.017$
[g] Non-ag/near-ag comparison in evening period: $P \leq 0.017$

Table 22. Mean counts of golden eagles at non-ag (>2 km from agriculture) and near-ag (≤2 km from agriculture) non-OTA sites in the Integration Study Area (ISA) during 10 seasons, from April 1991 to July 1994. (M = morning; A = afternoon; E = evening).

	ALL NON-OTA SITES			NON-AG SITES				NEAR-AG SITES			
Season	M	A	E	Total	M	A	E	Total	M	A	E
Breeding 1991											
N	120	120	115	217	74	74	69	138	46	46	46
Mean	0.08	0.17	0.13	0.10	0.05	0.12	0.13	0.17	0.13	0.24	0.13
SD	0.31	0.42	0.36	0.32	0.23	0.33	0.38	0.43	0.40	0.52	0.34
Dry 1991											
N	120	119	120	221	74	73	74	138	46	46	46
Mean	0.01	0.07	0.01	0.01	0	0.03	0	0.06	0.02	0.13	0.02
SD	0.09	0.28	0.09	0.09	0	0.16	0	0.26	0.15	0.40	0.15
Winter 1991-92											
N	119	116	119	220	74	73	73	134	45	43	46
Mean	0.05[b]	0.18[b]	0.14	0.13	0.08	0.16	0.15	0.11	0	0.21	0.13
SD	0.25	0.47	0.42	0.38	0.32	0.41	0.40	0.42	0	0.56	0.45
Breeding 1992											
N	120	120	120	222	74	74	74	138	46	46	46
Mean	0.07	0.13[c]	0.04[c]	0.08	0.07	0.12	0.04	0.09	0.07	0.15	0.04
SD	0.28	0.39	0.24	0.33	0.30	0.40	0.26	0.28	0.25	0.36	0.21
Dry 1992											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.05	0.07	0.09	0.04	0.04	0.04	0.05	0.11	0.07	0.11	0.15
SD	0.22	0.28	0.43	0.21	0.20	0.20	0.23	0.45	0.25	0.38	0.63
Winter 1992-93											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.08	0.19	0.11	0.13	0.10	0.21	0.08	0.12	0.04	0.17	0.15
SD	0.29	0.54	0.39	0.43	0.34	0.58	0.32	0.41	0.16	0.49	0.47
Breeding 1993											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.13	0.12	0.14	0.06	0.07	0.03[f]	0.08	0.24	0.22	0.26[f]	0.24
SD	0.38	0.35	0.40	0.26	0.25	0.16	0.32	0.49	0.51	0.49	0.48
Dry 1993											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.06	0.07	0.05	0.04	0.01	0.01	0.03	0.09	0.13	0.04	0.09
SD	0.24	0.25	0.25	0.20	0.11	0.11	0.16	0.31	0.34	0.21	0.35
Winter 1993-94											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.13	0.14	0.17	0.14	0.12	0.15	0.15	0.15	0.13	0.13	0.20
SD	0.36	0.40	0.47	0.40	0.33	0.40	0.46	0.43	0.40	0.40	0.50
Breeding 1994											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.11	0.12	0.12	0.09	0.11	0.05	0.10	0.16	0.11	0.22	0.15
SD	0.39	0.32	0.39	0.33	0.39	0.23	0.34	0.42	0.38	0.86	0.47

[a] Non-ag/near-ag comparison: $P \leq 0.05$
[b] Morning/afternoon comparison: $P \leq 0.017$
[c] Morning/evening comparison: $P \leq 0.017$
[d] Afternoon/evening comparison: $P \leq 0.017$
[e] Non-ag/near-ag comparison in morning period: $P \leq 0.017$
[f] Non-ag/near-ag comparison in afternoon period: $P \leq 0.017$
[g] Non-ag/near-ag comparison in evening period: $P \leq 0.017$

Table 23. Mean counts of Swainson's hawks at non-ag (>2 km from agriculture) and near-ag (≤2 km from agriculture) non-OTA sites in the Integration Study Area (ISA) during 10 seasons, from April 1991 to July 1994. (M = morning; A = afternoon; E = evening).

	ALL NON-OTA SITES			NON-AG SITES				NEAR-AG SITES			
Season	M	A	E	Total	M	A	E	Total	M	A	E
Breeding 1991											
N	120	120	115	217	74	74	69	138	46	46	46
Mean	0.12	0.11	0.25	0.08	0.09	0.04	0.12	0.28	0.15	0.22	0.46
SD	0.39	0.43	0.95	0.34	0.34	0.20	0.44	0.93	0.47	0.63	1.39
Dry 1991											
N	120	119	120	221	74	73	74	138	46	46	46
Mean	0.27	0.04	0.02	0.01[a]	0.01	0.01	0	0.27[a]	0.67	0.09	0.04
SD	2.74	0.24	0.18	0.09	0.12	0.12	0	2.56	4.42	0.35	0.29
Winter 1991-92											
N	119	116	119	220	74	73	73	134	45	43	46
Mean	0.02	0	0.03	0.02	0.03	0	0.04	0.01	0	0	0.02
SD	0.18	0	0.29	0.24	0.23	0	0.35	0.09	0	0	0.15
Breeding 1992											
N	120	120	120	222	74	74	74	138	46	46	46
Mean	0.09	0.06	0.02	0.04	0.05	0.12	0.01	0.09	0.15	0.02	0.15
SD	0.37	0.23	0.13	0.21	0.28	0.40	0.12	0.33	0.47	0.15	0.47
Dry 1992											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0	0.05	0	0.01	0	0.04	0	0.02	0	0.06	0
SD	0	0.29	0	0.15	0	0.26	0	0.19	0	0.33	0
Winter 1992-93											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0	0	0	0	0	0	0	0	0	0	0
SD	0	0	0	0	0	0	0	0	0	0	0
Breeding 1993											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.21	0.14	0.14	0.07	0.08	0.03[f]	0.08	0.36	0.41	0.30[f]	0.35
SD	1.00	0.51	0.40	0.30	0.36	0.20	0.32	1.14	1.53	0.76	1.02
Dry 1993											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.02	0.03	0	0.01	0.01	0.03	0	0.02	0.02	0.04	0
SD	0.13	0.18	0	0.12	0.11	0.16	0	0.15	0.15	0.21	0
Winter 1993-94											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0	0	0	0	0	0	0	0	0	0	0
SD	0	0	0	0	0	0	0	0	0	0	0
Breeding 1994											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.06	0.12	0.06	0.03	0.05	0.01[f]	0.03	0.15	0.07	0.28[f]	0.11
SD	0.27	0.47	0.27	0.18	0.23	0.12	0.16	0.51	0.33	0.72	0.38

[a] Non-ag/near-ag comparison: $P \leq 0.05$
[b] Morning/afternoon comparison: $P \leq 0.017$
[c] Morning/evening comparison: $P \leq 0.017$
[d] Afternoon/evening comparison: $P \leq 0.017$
[e] Non-ag/near-ag comparison in morning period: $P \leq 0.017$
[f] Non-ag/near-ag comparison in afternoon period: $P \leq 0.017$
[g] Non-ag/near-ag comparison in evening period: $P \leq 0.017$

Table 24. Mean counts of ferruginous hawks at non-ag (>2 km from agriculture) and near-ag (≤2 km from agriculture) non-OTA sites in the Integration Study Area (ISA) during 10 seasons, from April 1991 to July 1994. (M = morning; A = afternoon; E = evening)

	ALL NON-OTA SITES			NON-AG SITES				NEAR-AG SITES			
Season	M	A	E	Total	M	A	E	Total	M	A	E
Breeding 1991											
N	120	120	115	217	74	74	69	138	46	46	46
Mean	0.08	0.08	0.06	0.08	0.11	0.08	0.04	0.07	0.04	0.06	0.02
SD	0.33	0.32	0.27	0.32	0.35	0.32	.027	0.30	0.29	0.33	0.15
Dry 1991											
N	120	119	120	221	74	73	74	138	46	46	46
Mean	0	0	0	0	0	0	0	0	0	0	0
SD	0	0	0	0	0	0	0	0	0	0	0
Winter 1991-92											
N	119	116	119	220	74	73	73	134	45	43	46
Mean	0.03	0.01	0.02	0.02	0.04	0.01	0	0.01	0	0	0.04
SD	0.20	0.09	0.18	0.16	0.26	0.12	0	0.17	0	0	0.29
Breeding 1992											
N	120	120	120	222	74	74	74	138	46	46	46
Mean	0.04	0.09	0.06	0.04	0.04	0.04	0.03	0.11	0.04	0.17	0.11
SD	0.20	0.32	0.27	0.19	0.20	0.20	0.16	0.36	0.21	0.44	0.39
Dry 1992											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.01	0	0	0	0	0	0	0.01	0.02	0	0
SD	0.09	0	0	0	0	0	0	0.08	0.15	0	0
Winter 1992-93											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0	0	0	0	0	0	0	0	0	0	0
SD	0	0	0	0	0	0	0	0	0	0	0
Breeding 1993											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.08	0.07	0.08	0.09	0.11	0.10	0.07	0.05	0.04	0.02	0.09
SD	0.28	0.25	0.29	0.29	0.31	0.30	0.81	0.25	0.21	0.15	0.35
Dry 1993											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.01	0	0	0.004	0.01	0	0	0	0	0	0
SD	0.09	0	0	0.07	0.11	0	0	0	0	0	0
Winter 1993-94											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0
SD	0.09	0.09	0.09	0.12	0.12	0.12	0.12	0	0	0	0
Breeding 1994											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.03	0.04	0.02	0.03	0.03	0.04	0.03	0.02	0.02	0.04	0
SD	0.20	0.24	0.13	0.22	0.23	0.26	0.16	0.15	0.15	0.21	0

[a] Non-ag/near-ag comparison: $P \leq 0.05$
[b] Morning/afternoon comparison: $P \leq 0.017$
[c] Morning/evening comparison: $P \leq 0.017$
[d] Afternoon/evening comparison: $P \leq 0.017$
[e] Non-ag/near-ag comparison in morning period: $P \leq 0.017$
[f] Non-ag/near-ag comparison in afternoon period: $P \leq 0.017$
[g] Non-ag/near-ag comparison in evening period: $P \leq 0.017$

Table 25. Mean counts of rough-legged hawks at non-ag (>2 km from agriculture) and near-ag (≤2 km from agriculture) non-OTA sites in the Integration Study Area (ISA) during 9 seasons, from July 1991 to July 1994. (M = morning; A = afternoon; E = evening). Data for rough-legged hawks in the 1991 breeding season was incomplete.

	ALL NON-OTA SITES			NON-AG SITES				NEAR-AG SITES			
Season	M	A	E	Total	M	A	E	Total	M	A	E
Breeding 1991											
N											
MEAN											
SD											
Dry 1991											
N	120	119	120	221	74	73	74	138	46	46	46
Mean	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01	0	0	0.02
SD	0.09	0.09	0.09	0.09	0.12	0.12	0	0.08	0	0	0.15
Winter 1991-92											
N	119	116	119	220	74	73	73	134	45	43	46
Mean	0.19	0.14	0.20	0.14	0.23	0.05	0.14	0.24	0.13	0.28	0.30
SD	0.51	0.43	0.48	0.45	0.59	0.23	0.45	0.51	0.34	0.63	0.51
Breeding 1992											
N	120	120	120	222	74	74	74	138	46	46	46
Mean	0.27	0.18	0.13	0.16	0.16	0.14	0.19	0.23	0.43	0.24	0.02
SD	0.73	0.60	0.44	0.54	0.52	0.56	0.54	0.70	0.96	0.67	0.15
Dry 1992											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.06	0.12	0.06	0.04	0.01[e]	0.08	0.01[g]	0.14	0.13[f]	0.17	0.13[g]
SD	0.24	0.45	0.24	0.14	0.12	0.43	0.12	0.39	0.34	0.49	0.34
Winter 1992-93											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.23	0.21	0.24	0.16[a]	0.16	0.16	0.14	0.34[a]	0.33	0.28	0.41
SD	0.53	0.47	0.54	0.41	0.44	0.41	0.38	0.62	0.63	0.54	0.69
Breeding 1993											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.09	0.17	0.15	0.13	0.07	0.12	0.19	0.15	0.13	0.24	0.09
SD	0.29	0.54	0.56	0.50	0.25	0.47	0.68	0.45	0.34	0.64	0.28
Dry 1993											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.03	0.02	0.02	0.01	0[e]	0.01	0.03	0.04	0.09[f]	0.02	0
SD	0.18	0.13	0.13	0.12	0	0.11	0.16	0.19	0.28	0.15	0
Winter 1993-94											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.09	0.13	0.08	0.12	0.14	0.11	0.12	0.07	0.02	0.17	0.02
SD	0.34	0.43	0.33	0.40	0.42	0.39	0.41	0.31	0.15	0.48	0.15
Breeding 1994											
N	119	119	119	219	73	73	73	138	46	46	46
Mean	0.02	0.06	0.02	0.03	0.01	0.05	0.01	0.04	0.02	0.07	0.02
SD	0.13	0.27	0.13	0.16	0.12	0.23	0.12	0.22	0.15	0.33	0.15

[a] Non-ag/near-ag comparison: $P \leq 0.05$
[b] Morning/afternoon comparison: $P \leq 0.017$
[c] Morning/evening comparison: $P \leq 0.017$
[d] Afternoon/evening comparison: $P \leq 0.017$
[e] Non-ag/near-ag comparison in morning period: $P \leq 0.017$
[f] Non-ag/near-ag comparison in afternoon period: $P \leq 0.017$
[g] Non-ag/near-ag comparison in evening period: $P \leq 0.017$

Military activity was not found to influence the presence or abundance of raptors in either the 1993-94 non-breeding or the 1994 breeding season. Not only were raptor numbers low in these seasons, but we felt that military activity was less intense than in previous years. We recorded higher numbers of zero-zero counts during our paired observations, 57% of non-breeding season and 24% of breeding season pairs. After adjusting the 1991 and 1992 military activity data sets by the average increase in sites classified with military activity obtained from the GPS location data in 1993 and 1994, we concluded that we probably conducted fewer observations during military activity in all the 1993-94 seasons. The combined effects of low raptor numbers and low sample size in the military activity data set would make it difficult to find any statistically significant differences. The addition of the digitally located points or polygons of military activity in the OTA is a potentially good source of information, but the accompanying 'blanket' dates of activity creates a very misleading picture of military activity. A 'blanket' date, such as an assembly area with 150 personnel and 20 vehicles from May to July, is grossly inaccurate on a day to day basis. Activity may have occurred at a site for 5 consecutive days, then absent for 2 days waiting for the next military unit to move in. If our observation at a nearby count site occurred on 1 of the 2 vacant days, we would have correctly recorded no military activity at that site on our field observation form. However, according to the location information we received, we would have to consider that site as having military activity. With no *a priori* knowledge of the length of time it takes for a bird to return to an area following military activity, we chose a maximum of 3 hours prior to our observation as the time span over which raptor presence in an area may be influenced. Without being able to determine if military activity even occurred on the same day as our observation, the additional location information is useless and has the potential to dilute the true military activity data set to an incalculable degree. We examined how our military activity data set changed when we excluded the GPS location information. Sixteen counts changed from military activity to no military activity. However, only 3 of those changes occurred within our paired observations data set, and only 1 of those was a pair with dissimilar results which would have changed our contingency table data. Unfortunately, our data are too sparse to examine this problem adequately. Digitally locating points of military activity is a tremendous step forward in the effort to assess the impacts of military activity on raptors, but it must be accompanied by accurate, at least to within a day, dates of use.

Re-analysis of our habitat association data, using the corrected the vegetation map, revealed many more significant associations than reported previously (Strickler and Watson 1993). Several interesting trends emerged with the new analyses. Many species tended to change their habitat associations during and following the 1992 breeding season drought. Northern harriers, red-tailed hawks, and rough-legged hawks were always associated to some degree with agriculture, and their association was even stronger in 1992 and the 1993 breeding season. Even species that normally do not associate with agriculture, such as prairie falcons and golden eagles, used these areas more in the 1992 seasons than in other years or seasons. Also, diurnal differences in occurrence of particular species in various habitats became apparent. Golden eagles consistently associated with sagebrush and shrub mosaic areas in all seasons, but exhibited different and distinct diurnal use patterns in the breeding and non-breeding seasons. Eagles may have different nutritional and/or territorial needs in the 2 types of seasons, and we may be observing 2 potentially different eagle populations; the breeding birds and the winter migrants. The year-round resident breeding eagles show different foraging patterns in the breeding and non-breeding seasons, and the over-wintering migrants use the OTA to a greater extent than the resident breeders in the non-breeding seasons (Marzluff et al., this volume). Our habitat association results lend support to their conclusions.

The changes and trends that became evident with correction of the vegetation data highlights the importance of having an accurate vegetation map. Unfortunately, they also highlight the potential for error in the current map. We caution other studies to use the current map with care and to field-check important areas. We applaud current efforts to improve vegetation identification by redefining the spectral values over smaller regional units within the ISA.

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Appendix A. Species totals and total counts for 1991 breeding (Br.), 1991 dry, 1991-92 winter, 1992 breeding, 1992 dry, 1992-93 winter, 1993 breeding, 1993 dry, 1993-94 winter, and 1994 breeding seasons.

Species	91 Br.	91 Dry	91/92 Winter	92 Br.	92 Dry	92/93 Winter	93 Br.	93 Dry	93/94 Winter	94 Br.
Total counts	559	567	564	570	567	567	567	567	564	567
All species	2291	1047	1827	1835	957	1329	1791	794	1175	1155
All raptors	816	254	484	585	201	341	791	138	264	467
Common raven	1475	793	1343	1250	756	988	1000	656	911	687
Northern harrier	226	47	117	148	29	69	228	36	54	112
Prairie falcon	163	24	54	72	17	49	114	12	34	66
Red-tailed hawk	92	33	39	56	23	9	110	17	15	62
Golden eagle	80	19	80	49	35	59	70	28	82	61
Swainson's hawk	77	40	6	28	6	1	72	6	0	36
Ferruginous hawk	47	5	8	33	3	0	40	4	3	24
Rough-legged hawk	21	4	95	121	30	111	74	8	52	19
Short-eared owl	21	1	0	10	2	5	1	0	0	7
American kestrel	13	8	8	8	20	5	23	5	5	27
Burrowing owl	5	3	0	1	0	0	3	1	0	17
Turkey vulture	5	16	0	7	8	0	6	10	0	18
Bald eagle	0	0	10	2	0	6	1	0	3	0
Cooper's hawk	2	0	1	0	1	0	0	1	0	1
Sharp-shinned hawk	1	1	2	0	3	0	0	1	0	2
Northern goshawk	0	0	0	0	1	0	1	0	0	0
Merlin	0	0	0	0	0	0	0	0	3	1
Unidentified	63	53	64	50	23	27	48	9	13	14
Unidentified (%)	3.0	5.0	3.5	3.0	2.4	2.0	2.7	1.1	1.1	1.2

Habitat Relationships of Townsend's Ground Squirrels

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ANNUAL SUMMARY

*During our fourth field season, January through June, of a planned 4-yr study, we continued to collect information to describe differences in population processes for Townsend's ground squirrels (**Spermophilus townsendii**) among habitats and among years. We extended our collection of basic demographic data from our 20 study sites that differ in vegetation type, fire history, and history of tracking by armored vehicles. In 1994, adult densities declined, and numbers of juveniles captured increased relative to 1993.*

Experimental tracking by armored vehicles at the end of the 1992 above-ground season did not produce any apparent differences in ground squirrel density.

Constant addition of food to 2 sites during the active seasons of 1993 and 1994 resulted in high densities and high per capita reproduction relative to control sites in 1994.

Mean masses of adults in 1994 were similar to those in non-drought years of 1991 and 1993. Food supplementation did not increase mean masses. Maximum running speed was not influenced by body mass within the range of masses that we were able to test.

***Poa secunda**, a native bunchgrass that is a common food item, desiccated early in the season, similar to the pattern in the 1992 drought. Differences in diet among habitats in 1993 were similar to the patterns in 1991 and 1992. When **P. secunda, Ceratoides lanata, Artemisia tridentata,** and **Bromus tectorum** were offered in cafeteria tests, there were no consistent trends in food preference between late March and mid-May. Mean dry weights consumed during the cafeteria trials were similar among plant species.*

OBJECTIVES

1. To determine whether Townsend's ground squirrel densities, survival rates, and productivity differ:

   a) among habitat types.

   b) between areas that have been subjected to experimental tracking by armored vehicles and those that have not.

   c) between burned and unburned areas.

   d) between burned areas that have been seeded and those that have not been seeded.

2. To evaluate the role of food in determining density, body mass, and reproduction by adding food experimentally.

To identify the processes that are producing the observed among-habitat patterns, we addressed questions that represent hypotheses:

1. How does body mass vary with habitat? How does body mass influence survival through the torpid period and reproduction?

2. What is the role of vegetation (percent cover and phenology) in determining diet? Are different diets associated with different patterns of mass gain?

3. What are the preference rankings among the 3 main food items? Given the extensive and expanding invasion of cheatgrass in the Snake River Birds of Prey National Conservation Area (SRBOPNCA), is this a preferred food item?

METHODS

Study Sites

Sites are identical to those described previously (Table 1, Fig. 1, Van Horne et al. 1993a).

Table 1. Site pairs for sampling of Townsend's ground squirrels in the Snake River Birds of Prey Area.

Habitat Type	
Winterfat outside the Orchard Training Area (OTA)	1a, 1b
Sagebrush outside the OTA	2a, 2b
Sagebrush/Winterfat outside the OTA	3a, 3b
Burned Sagebrush inside the OTA	4a, 4b
Sagebrush inside the OTA	5a, 5b
Burned Winterfat outside the OTA	6a, 6b
Burned Sagebrush/Winterfat outside the OTA	7b, 8b
Burned Sagebrush/Winterfat outside the OTA with food added	7a, 8a
Sagebrush inside the OTA tracked in 1992	9a, 9b
Burned sagebrush inside the OTA tracked in 1992	10a, 10b

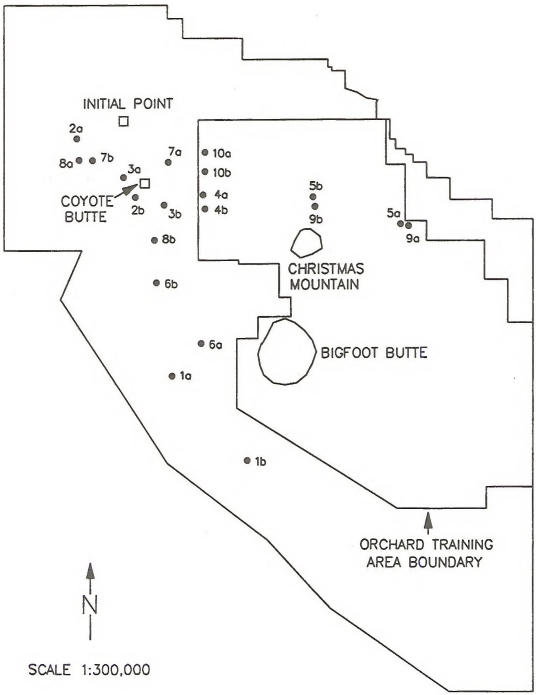

Fig. 1. Study site locations in the Snake River Birds of Prey National Conservation Area near Boise, Idaho, 1994 (see Table 1 for site types).

Density Estimation

As in previous years (Van Horne et al. 1992, 1993*a*), we estimated density by dividing estimates of population size by the estimated area covered by the trapping grid. However, because we did not use assessment line trapping in 1994, we used the area estimates from 1993. This seemed reasonable as trapping grid sizes were the same in both years.

We computed population estimates for adults in 1994 using open population estimation modeling techniques similar to those used in 1993 (Van Horne et al. 1993*a*). We again used the special case of Jolly-Seber models known as "death only" or "no-recruitment" to compute estimates of numbers of adults at time of emergence from hibernation. In most cases, we were forced to pool data from 2 or more sites to obtain site-specific estimates because of small sample sizes. This was accomplished by further modifying the SAS Proc NLIN (SAS Institute Inc. 1990) program used previously to allow us to compute common survival and capture parameters across sites. We combined sites within general treatment categories; OTA burn sites (4a, 4b, 10a, and 10b), OTA sage sites (5a, 5b, 9a, and 9b), off-OTA burn sites without supplemental feeding (6b, 7b, and 8b), and off-OTA shrub sites (3a and 3b). The supplemental feeding sites (7a and 8a) had sufficient sample sizes to compute site-specific estimates without pooling.

We examined up to 40 possible models for each combination of sites. These included models with per-day survival rates constrained as constant through time or varying as a linear function of time, and capture rates modeled as constant or varying as a linear or quadratic function of time. For all of these models, we also examined site as a factor using both additive and interactive models. "Best" models were selected based on the criteria: (1) low AIC (Akaike's Information Criterion, Akaike 1973, 1985), (2) reasonable parameter estimates, especially of population size but also of survival and capture rates, and (3) model parsimony (fewer parameters), because of the better precision of the estimates from these models.

Tracking

On 16 and 17 June 1992, sites 9a, 9b, 10a, and 10b were tracked by an M1 tank driven by IDARNG personnel. Site 10a was inadvertently tracked again in August 1993 by several tanks. The amount of soil and vegetation disturbance exceeded that associated with the experimental tracking. We continued to monitor these sites and compare them with sites that had not been experimentally tracked.

Supplemental Feeding Experiment

We have previously provided a detailed description of methods for our supplemental feeding experiment (Van Horne et al.1993*a*). In brief, we randomly chose 2 sites as treatments (Sites 7a and 8a) and 2 sites as controls (Sites 7b and 8b). In 1993 and 1994, we supplied food every time that we trapped the treatment sites, which averaged ca. once per week. To supply food as evenly as possible to the sample population, we used 126 evenly spaced feeding locations, which we shifted following 4 configurations (Van Horne et al. 1993*a*) to obtain reasonable spatial coverage. Each of the 126 feeding locations was supplied with 155 g of alfalfa and ca. 35 g of apple (typical wet weight of "standardized" slices). Therefore, on each day that a treatment was applied, we supplied a 4.5-ha grid with 19.5 kg of alfalfa pellets and 4.4 kg of apple.

We have completed nutritional analyses of samples of the alfalfa (Table 2), so that we can compare the nutritional value of the supplemental food with natural forage. We analyzed samples separately for 1993 and 1994 (Table 2) because the supplier changed between years. We provided apples to the squirrels primarily to add water to their diet. Water constitutes ca. 85% of the mass of apples (Holland et al. 1992). In general, apples are low in protein (<3% dry weight) and lipids (<1% dry weight), but contain moderate energy (ca. 3100 cal/g) mostly due to carbohydrates (Holland et al. 1992).

Body Mass and Body Condition

Live Animals in the Field.--For general trapping methods, see Van Horne et al. (1992). We weighed each animal captured during livetrapping with a spring scale. Only masses from the first capture of an individual within a day were used in calculations. We assessed overwinter persistence of ground squirrels through the 1993-94 winter in the same manner as described previously (Van Horne et al. 1992).

Table 2. Nutritional characteristics of alfalfa used in supplemental feed experiment in 1993 and 1994. The fiber components are based on neutral detergent fiber (NDF) and acid detergent fiber (ADF).

Nutritional measurement	1993	1994
Gross energy (cal/g)	4010	4047
Protein (%)[a]	17.19	17.31
Lipid (%)	3.87	4.16
Hemicellulose (%)	9.86	11.53
Cellulose (%)	26.23	29.92
Lignin (%)	6.04	7.77
Silica (%)	0.23	0.16
NDF (%)	42.36	49.38
ADF (%)	32.50	37.85

[a]Protein (%) = 6.25 x nitrogen (%).

Maximum Running Speed.--Ground squirrels that live in open environments primarily respond to predators by running to a burrow for refuge. Maximum running speed (MRS) should be one factor that determines the probability of mortality due to predators. We were mainly interested in whether body mass affected MRS, and also whether distance run influenced MRS. MRS is negatively correlated with body mass for Belding's ground squirrels (*Spermophilus beldingi*, Trombulak 1989), but evidently not for golden marmots (*Marmota caudata aurea*, Blumstein 1992).

We conducted a pilot study in 1993 on a burned area (not 1 of our 20 study sites) and attempted a more extensive study in 1994 on a different burned area (Site 8a and adjacent habitat). We livetrapped squirrels from 14 April-2 May in 1993 and from 29 March-19 April in 1994. We retained only adult males for trials, because we were concerned that body mass of adult females could be confounded by their reproductive status and history. We marked adult males with black dye and sometimes PIT tags for identification, and recorded relevant capture information (body mass, reproductive condition, capture status). We kept individuals in covered cages, in the shade, prior to time trials.

We conducted the time trials on 1 running track in 1993 and on a different track in 1994. The tracks were compact dirt substrates (0.5 m wide). To force squirrels to run on the tracks, we erected particle boards (0.4 m high) on both sides along the length of the tracks. Incline can influence MRS of sciurids (Blumstein 1992). Our tracks were flat (<0.5 degree mean deviation from level based on 10 measurements at 1-m intervals), and we ran all individuals in the same direction on each track. We marked 3 distances on the tracks: start (0 m), middle (5 m), and finish (10 m).

For a trial, we released an animal from its trap, and 1 person chased it down the track by running behind it, yelling loudly, and beating the ground and running boards with a sage branch. Other researchers (Trombulak 1989, Blumstein 1992) have used similar methods to encourage other sciurids to run at maximum speeds. During initial trials in 1994, however, some squirrels did not seem to respond to the human stimulus, evidently because they had been captured and handled repeatedly on Site 8a. Therefore, for all 1994 trials presented herein, we also used a domesticated dog (38-kg male retriever mix) to function as a canid predator and to encourage the squirrels to run at full speed. The dog was staked near the start line, so that the

"predator" and "prey" could see and smell each other, but no physical contact was allowed. Thus, procedures were identical for trials in 1993 and 1994 except for the use of the canid predator in 1994.

To avoid timing squirrels before they had responded to the chaser, we released the animals 1.5 m before the start line. The same 2 people recorded all running times with hand-held stopwatches that were synchronized prior to each trial. One person recorded the start time and sometimes the 5-m split time; the other person recorded the 10-m finish time and sometimes the 5-m split. According to trials in 1994 when both timers recorded 5-m split times, the timers were consistent ($\bar{x} = 0.06$ sec difference, SE = 0.01, $n = 16$). For those trials when both timers recorded the 5-m split, we used the time from the person who recorded the finish time. The end of the track was not blocked, so squirrels continued to run past the finish line. If squirrels hesitated substantially during the run, we did not include their data in analyses.

Our general design was to attempt to recapture individuals throughout the season and obtain repeated measurements of MRS at different body masses. We also used a within-subject design to test for effects of distance, because we measured MRS for both the 0-5 m and the 5-10 m splits. We tested for differences between the 2 split times with a Wilcoxon Signed Rank Test (Conover 1980:280).

Vegetation

General.--We sampled vegetation (Van Horne et al. 1991) on all sites during 3 different periods: 28 February - 10 March, 13 - 20 April, and 23 - 30 May. These corresponded with 3 periods in which we collected fecal samples for dietary analysis: 20 February - 10 March, 10 - 24 April, and 18 - 31 May. Some plant phenology information comes from this data set, because we classified plants as either succulent or desiccated.

Plant Phenology.--We recorded basic plant phenology data for common species of grasses and forbs on our 20 study sites on every trapping occasion, about once per week. Species were categorized according to vegetative stages that included (1) early growth, leaves/blades unfolding, (2) mostly to fully developed, generally coinciding with presence of reproductive structures, (3) withering and drying, and (4) desiccation of above-ground growth. Desiccation was based on the color and texture of vegetative structures. We recorded the date when individuals on a site first reached a certain stage, and when most (>50%) individuals reached that stage.

Diet

Fecal Samples.--We collected 73 fecal samples from adults during the first period, 77 samples from adults and 61 samples from juveniles during the second period, and 81 samples from juveniles during the third period. Fecal samples have not been analyzed, as laboratory processing through the Composition Analysis Lab in Fort Collins, CO takes at least 6 months. Data from the 1993 season will therefore be presented here.

Repeatability of Diet Determination.--The Compositional Analysis Lab quantified the diet of squirrels by using a microhistological technique, in which plant species were identified in fecal samples of squirrels by matching epidermal patterns from the samples with epidermal patterns from reference material. Dried samples were ground over a 1-mm mesh screen, and then 20 fields were read from a prepared microscope slide. According to the lab, 1 slide per sample should provide at least a ranked list of items in the sample, whereas 5 slides per sample is recommended to estimate a percent relative density of items. We have used 1 slide per sample to estimate diet, so we evaluated the repeatability of the lab in estimating percent relative density of diet items in our samples.

Our design was to select 3 samples from 1993 from each of 3 habitats (burn, sagebrush, and winterfat) and from each of our 3 sampling periods. We were unable to obtain samples from the winterfat habitat for the third period, however, so we used 24 samples. We divided each of these samples into three subsamples. We created the subsamples by dividing individual pellets into 3 equal pieces and then placing each piece into 1 of the 3 subsamples. The choice of samples and the placement of material into subsamples was done in a haphazard, unbiased manner. All subsamples were placed in whirl paks and labeled following normal procedures, except 2 of the 3 subsamples were

given false identification numbers. The lab was not notified of our evaluation, and thus it was a blind test.

We assessed the repeatability of the technique by calculating a similarity index (Anthony and Smith 1977, Wydeven and Dahlgren 1982) for each set of 3 subsamples, which was calculated as:

$$SI = \sum_{i=1}^{n} Y_i$$

where Y_i equaled the lowest percentage value of a shared diet item and n equaled the total number of items. A SI of 100% would indicate that the 3 subsamples were identical. The similarity indexes were compared among habitat types and periods using an ANOVA with multiple effects.

Cafeteria Tests.--For each trial we collected ca. 15 g (wet weight) of each of 4 forage items, *Poa secunda, Ceratoides lanata, Artemisia tridentata,* and *Bromus tectorum*, on the afternoon prior to the trials. We used the most succulent samples we could find on the SRBOPNCA. We included the crowns in the bluegrass samples; these were washed to remove loose soil and stones. We attempted to sample 3 animals captured on the same site. These were placed in laboratory cages in shade, and allowed to acclimate for at least 10 min. About 15 g of each of the 4 forage types was introduced into each cage, and similar amounts were held back as controls. We removed animals after 1½ to 2 hrs and released them at their point of capture on the trapping grid. Remaining samples were dried at 65 C for 24 hours or until weight had stabilized. We used dry/wet weight of the control samples to estimate initial dry weight of the treatment samples, which was, in turn, compared with post-treatment dry weights to estimate dry grams of forage consumed. We used only trials in which at least 0.5 g dry weight of forage had been consumed for our analyses.

Forage Quality.--Squirrels were collected during 2 periods during the 1993 season for analyses of their stomach and fecal contents. We collected squirrels either through shooting or the use of snap traps in OTA burned sagebrush and OTA sagebrush habitats from 2-13 March and 17-22 May 1993, corresponding with fecal collections during the mark-recapture portion of Study 4. We were unable to collect animals from winterfat habitats because of low animal densities. Stomach and fecal samples were collected and dried at 65 C for 48 hours. Stomach samples were analyzed for acid detergent fiber (ADF), neutral detergent fiber (NDF), lignin, nitrogen, gross energy, and lipid content by the Nutrient Analysis Laboratory at Colorado State University, Ft. Collins, to obtain an estimate of forage quality in different habitats and at different times of the season. In addition, matched stomach and fecal samples from individuals were analyzed by the Composition Analysis Laboratory at CSU to calibrate fecal analyses for differences in digestibility.

RESULTS AND DISCUSSION

Livetrapping

We trapped each of our 20 sites on 5-25 days ($\bar{x}$ = 17) from 1 February to 21 June (Table 3). On sites where we captured ≤1 pregnant female, we trapped fewer days during juvenile emergence. We usually trapped each site for 2 or 3 sessions per day with ca. 66 traps per session during the adult-only phase. We increased the number of traps per session during juvenile emergence (generally 80 to 100 traps). Our total effort resulted in 67,013 trap sets (Table 3), which was the greatest trap effort on grids during our 4-year study.

Density Estimation

As in previous years, we combined sexes to compute population size estimates of adults, and sex-specific estimates are based on the sex ratio of captured ground squirrels (Table 4). The models used to derive estimates varied, but generally were those with constant per-day survival rates and capture rates modeled with increasing complexity as sample sizes increased.

Although we have not yet conducted statistical tests, adult densities were substantially lower in 1994 than in 1993 (Table 4, Van Horne et al. 1993a). The total number of juveniles captured increased on all

Table 3. Trapping effort for Townsend's ground squirrels on 20 study sites at the Snake River Birds of Prey National Conservation Area, 1 February-21 June 1994. Trapping grids were 4.5 ha on all sites.

Site	Number of days trapped	Number of sessions	Number of traps set
1a	5	14	916
1b	5	14	919
2a	5	15	985
2b	6	18	1,177
3a	19	54	3,498
3b	18	49	3,180
4a	20	54	3,872
4b	21	57	3,988
5a	20	54	3,503
5b	23	61	4,680
6a	7	20	1,294
6b	20	56	3,933
7a	24	63	4,971
7b	19	53	3,690
8a	25	66	5,181
8b	20	56	3,752
9a	19	51	3,571
9b	21	56	3,711
10a	24	65	4,826
10b	27	70	5,366
Total	348	946	67,013

sites except food supplemented site 8a, burn 8b, andsage site 9b. The only substantial decrease in juvenile captures between years was on site 9b (Table 5). Adult densities on the supplemental sites were similar before and after supplementation began in 1993, but densities on their control sites (the burns) declined substantially after 1993. The supplemental feeding sites again had higher densities of adults and juveniles than any other sites.

Offspring Production

Numbers of offspring per female met or exceeded 2 (the minimum number for potential replacement of adults) on burn sites 4b (OTA) and 8b, tracked and burned site 10a (OTA), sagebrush site 5a (OTA), and both the sites to which food was added (7a and 8a). Overall, values were similar to those in 1992 and higher than those in 1993 (Table 6).

Chronology of Annual Activity and Reproduction

Adult male Townsend's ground squirrels emerge before adult females in some years (Van Horne et al. 1993*a*). In 1994, an extended period of below average temperatures and snow on the ground in February made it difficult to examine sexual differences in emergence. We first captured squirrels on most sites in late February, and by then we captured both adult males and females. We trapped 1 site (8a) in early February (1 - 3 Feb) prior to the inclement weather. On this site, the sex ratio of captures was skewed towards males (ca. 75% males) in early February, whereas it was skewed towards females (ca. 25% males) on capture occasions throughout the remainder of the season. This pattern suggests that males probably emerged earlier than females on this site.

Table 4. Density estimates of adult Townsend's ground squirrels for sites in the Snake River Birds of Prey Area, 1994, at emergence from hibernation.

Site	Grid Area (ha)	Strip Width (m)	Adjusted Area (ha)	Sex	MNA[a]	Proportion of Total	Estimated Population Size	Density (#/ha)
1a	4.50	15.00	5.18	M	0		0	
				F	0		0	0.00
1b	4.50	15.00	5.18	M	0	0.00	1	0.00
				F	1	1.00	0	0.00
2a	4.50	15.00	5.18	M	0		0	0.00
				F	0		0	0.00
2b	4.50	15.00	5.18	M	0		0	0.00
				F	0		0	0.00
3a	4.50	15.00	5.18	M	1	0.50	2	0.39
				F	1	0.50	2	0.39
3b	4.50	15.00	5.18	M	4	0.50	6	1.16
				F	4	0.50	6	1.16
4a	4.50	51.94	6.88	M	4	0.25	5	0.73
				F	12	0.75	13	1.89
4b	4.50	51.94	6.88	M	2	0.22	3	0.44
				F	7	0.78	8	1.16
5a	4.50	15.00	5.18	M	5	0.45	8	1.54
				F	6	0.55	10	1.93
5b	4.50	15.00	5.18	M	10	0.52	15	2.90
				F	9	0.48	13	2.51
6a	4.50	51.94	6.88	M	0		0	0.00
				F	0		0	0.00
6b	4.50	51.94	6.88	M	2	0.25	4	0.58
				F	6	0.76	12	1.74
7a	4.50	34.50	6.07	M	8	0.35	10	1.65
				F	15	0.65	20	3.29
7b	4.50	51.94	6.88	M	2	0.33	4	0.58
				F	4	0.67	8	1.16
8a	4.50	34.50	6.07	M	27	0.33	40	6.59
				F	57	0.67	81	13.34
8b	4.50	51.94	6.88	M	2	0.67	5	0.73
				F	1	0.33	3	0.44
9a	4.50	15.00	5.18	M	2	0.18	4	0.77
				F	9	0.82	16	3.09
9b	4.50	15.00	5.18	M	4	0.44	7	1.35
				F	5	0.56	9	1.74
10a	4.50	51.94	6.88	M	6	0.67	7	1.02
				F	3	0.33	4	0.58
10b	4.50	51.94	6.88	M	8	0.50	10	1.45
				F	8	0.50	10	1.45

[a]Minimum Number Alive

Table 5. Number of juvenile Townsend's ground squirrels captured, by sex and overall, on sites in the Snake River Birds of Prey Area, 1994. Dashes indicate sites not trapped during juvenile emergence because fewer than 2 adult females were captured earlier in the active season.

	Number Captured						
	Female		Male		Sex Unknown	Total	
Site	1993	1994	1993	1994	1993	1993	1994
1a	0	-	0	-	0	0	-
1b	0	-	0	-	0	0	-
2a	0	-	0	-	0	0	-
2b	0	-	0	-	0	0	-
3a	0	1	0	1	0	0	2
3b	0	4	2	1	0	2	5
4a	3	6	6	10	0	9	16
4b	16	17	6	13	1	23	40
5a	1	4	2	7	0	3	11
5b	4	17	3	15	0	7	32
6a	0	-	0	-	0	0	-
6b	1	8	2	3	0	3	11
7a	29	35	36	52	0	65	87
7b	1	7	1	7	0	2	14
8a	43	37	42	44	0	85	81
8b	5	4	8	2	0	13	6
9a	2	2	1	5	0	3	7
9b	19	3	12	5	0	31	8
10a	3	18	11	22	0	14	40
10b	17	15	19	26	0	36	41

Table 6. Index of reproduction for Townsend's ground squirrels in the Snake River Birds of Prey Area calculated for 1992 as the quotient of juvenile densities prior to 1 May and adult densities prior to the first juvenile capture on each site, and for 1993 as the quotient of the Minimum Number of Alive (MNA) of juveniles captured prior to 1 May and the MNA of adults captured prior to 1 April.

Site		1992 Reproductive Index	1993 Reproductive Index	1994 Reproductive Index
Winterfat	1a	1.1	0.0	0.0
	1b	0.0	0.0	0.0
Sagebrush	2a	0.0	0.0	0.0
	2b	1.2	0.0	0.0
Sage/Winterfat	3a	0.0	0.0	1.0
	3b	1.6	2.0	0.6
OTA Burn	4a	0.1	0.2	1.1
	4b	0.1	1.6	5.7
OTA Sagebrush	5a	0.7	1.7	2.0
	5b	1.3	0.1	1.6
Burned Winterfat	6a	0.0	0.0	0.0
	6b	0.4	0.0	1.8
Burn + Food	7a	1.2	1.0	3.3
	8a	2.0	0.4	2.8
Burn	7b	1.2	0.3	1.0
	8b	0.3	0.7	5.0
OTA Sage	9a	0.8	0.2	1.5
	9b	1.3	0.8	1.4
Burn + Tracked	10a	0.3	0.8	2.8
	10b	0.4	0.4	1.7

Much of the annual variation in the timing of reproductive events for squirrels is probably determined by the emergence dates of adult females, because females evidently breed soon after emergence, and males are scrotal by that time (Van Horne et al. 1993*a*). In 1994, we typically first captured lactating females in late March, and we first captured juveniles in mid-April (Table 7). The timing of reproduction in 1994 was similar to dates for 1993, which was another year when late winter weather evidently delayed emergence of adult females until late February (Van Horne et al. 1993*a*).

All males captured were reproductively active during the height of the breeding season in February. By 15 April none was found with testes descended (Table 8).

Table 7. Dates of first capture of an adult female, lactating female, and juvenile Townsend's ground squirrel at the Snake River Bird of Prey National Conservation Area, 1994. Medians and ranges are presented for multiple study sites (n). Capture success was too low on some sites to determine dates.

Variable	n	Median	Range
Adult female	10	23 Feb	1 Feb - 2 Mar
Lactating female	7	26 Mar	17 Mar - 31 Mar
Juvenile	14	13 Apr	30 Mar - 28 Apr

Table 8. Mean *(n)* percent of Male Townsend's Ground Squirrels in the Snake River Birds of Prey Area reproductive as indicated by descended testes in 1994 by week.

Dates	% Reproductive (n)
≤27 Jan	95(22)
>27 Jan and ≤ 3 Feb	100(11)
>3 Feb and ≤10 Feb	100(3)
>10 Feb and ≤17 Feb	100(2)
>17 Feb and ≤24 Feb	92(25)
>24 Feb and ≤4 Mar	46(13)
>4 Mar and ≤11 Mar	30(10)
>11 Mar and ≤18 Mar	14(7)
>18 Mar and <25 Mar	9(11)
>25 Mar and ≤1 Apr	0(13)
>1 Apr and ≤8 Apr	10(19)
>8 Apr and ≤15 Apr	4(22)
>15 Apr	0(101)

Sexual differences in the timing of immergence of adult squirrels may vary among years (Van Horne et al. 1993*a*). Males may immerge before females in some years. In 1994, males were last captured after females on 3 sites, females were captured last on 4 sites, and both sexes were last captured on the same date on 3 sites. These data should be interpreted with caution, however, because the overall number of captured squirrels was low on most sites. In general, most adult squirrels immerged in May, and juveniles immerged during June.

Persistence through the Torpid Period

The percentage of animals recaptured following the 1993-94 torpid period was much lower than the percentage following the 1991-92 torpid period, and lower for adult and juvenile males than the percentage following the 1992-1993 torpid period (Fig. 2). Adult male persistence declined between years on the winterfat, sagebrush, burned, and food supplemented sites (Fig. 3). Persistence of adult and juvenile females was highest on the food supplemented sites.

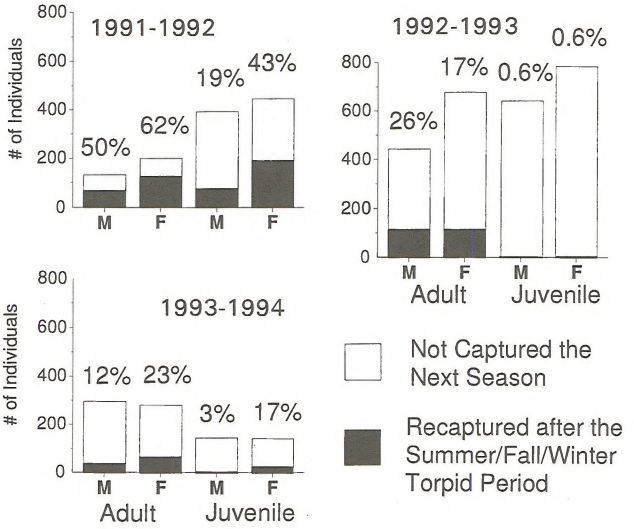

Fig. 2. Numbers of Townsend's ground squirrels of each age and sex class trapped in 1991, 1992, and 1993 (total bars), and numbers recaptured after the following torpid season (solid bars). Percent recaptured is indicated at the top of each bar.

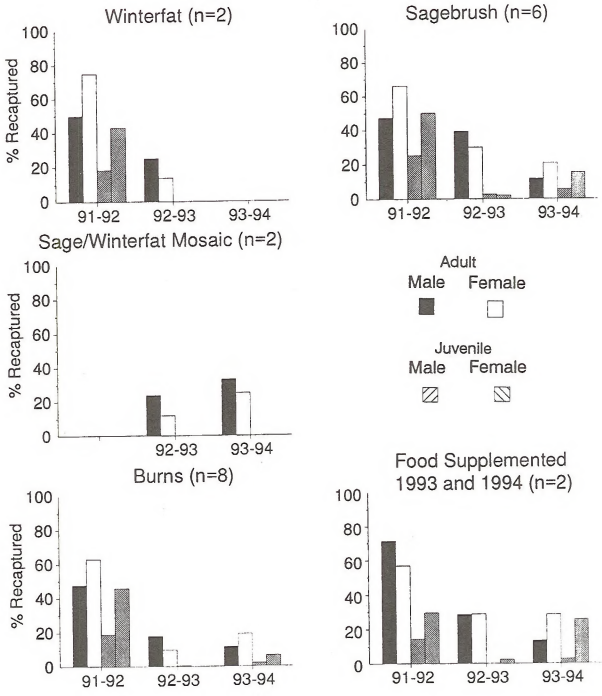

Fig. 3. Percent of Townsend's ground squirrels in each age and sex class present each year that were recaptured following the torpid season, averaged for sites within habitat types.

Sex Ratio

Although the female skew in the sex ratio has increased significantly with density during each of the 3 previous years, no such trend occurred in 1994. It appears that maximum density was too low for any such relationship to be manifested.

Body Mass

Mean masses of all animals captured on the same day appeared to be similar to those in 1991 and 1993, and higher than those of the 1992 drought year (Fig. 4). Juvenile male masses appeared to be lower on the sagebrush sites than on sites in other habitats (Fig. 5). There was a slight tendency for adult male masses to be higher on the supplemental food sites than on the burn sites (controls; Fig. 5).

Minimum masses of animals persisting through the torpid period across all sites were lower for 1993 adult males than they had been for 1991 and 1992 animals, but minima for the other sex/age classes were similar to those of previous years (Table 9).

Maximum Running Speed.--We were unable to obtain large samples of individuals to test our hypotheses, due to the low densities of adult males following the extreme drought of 1992. We conducted complete trials (times for the 0-5 m and 5-10 m splits) for 5 individual adult males in 1993, and for 11 males in 1994 (Fig. 6). We obtained repeat measurements for only 1 individual in 1993 and 3 individuals in 1994 (Fig. 6). Therefore, we were unable to use a within-subjects design to test for effects of body mass on MRS. Instead, we used a between-subjects design and correlated body mass and MRS among individuals (Trombulak 1989). For analysis, we used only data from the 1994 trials, and we randomly selected 1 trial from individuals with >1 trial so that observations were independent (Blumstein 1992). Body mass and MRS were not correlated (r_s = 0.24, P = 0.48, n = 11). We also detected no difference in MRS between the 0-5 m and the 5-10 m splits(t = 0.3406, P = 0.74, n = 10), which indicated that distance did not influence MRS, at least up to 10 m. Our results should be interpreted with caution, however, due to the small sample sizes.

Vegetation

Plant Phenology.--Seasonal changes of 2 plant species *(Poa secunda* and *Ranunculus testiculatus*) demonstrate typical phenology patterns for 1994. We have previously reported phenology patterns for these 2 species for 1992 and 1993 (Van Horne et al. 1993*b*). In our analyses, we have used the dates

Table 9. Minimum masses on the day of last capture for Townsend's ground squirrels whose last capture was on or after 1 May. Sample size in parentheses. Animals found to be present the following year are indicated as 'Recaptured'.

	Adult Males	Adult Females	Juvenile Males	Juvenile Females
1991				
Recaptured	225(25)	140(45)	104(54)	81(121)
Not Recaptured	228(21)	146(21)	48(139)	53(123)
1992				
Recaptured	202(32)	139(26)	108(3)	97(6)
Not Recaptured	139(72)	100(205)	38(302)	42(386)
1993				
Recaptured	186(24)	142(35)	113(4)	87(24)
Not Recaptured	167(100)	133(76)	49(100)	46(85)

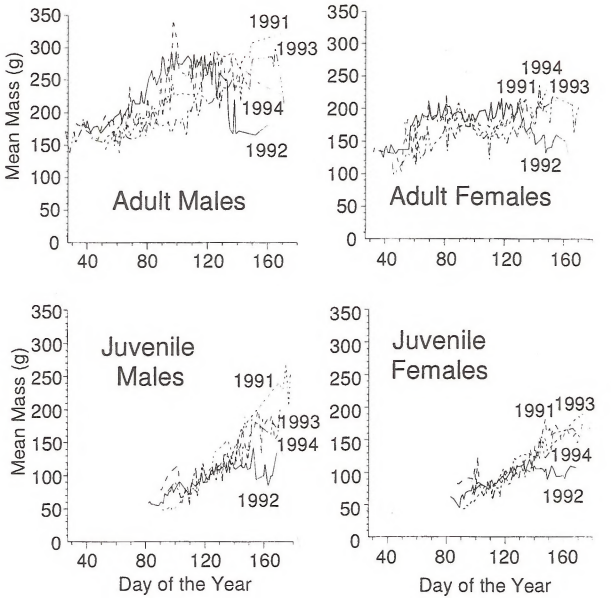

Fig. 4. Body mass averaged across sites for each sex and age class of Townsend's ground squirrels from the Snake River Birds of Prey Area for 4 years.

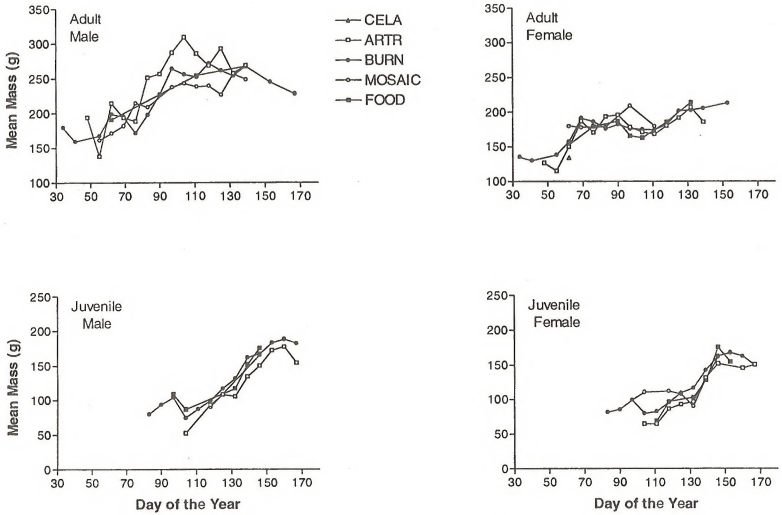

Fig. 5. Townsend's ground squirrel body mass averaged within weeks for site types trapped on the Snake River Birds of Prey Area during 1994. Age and sex classes are shown separately.

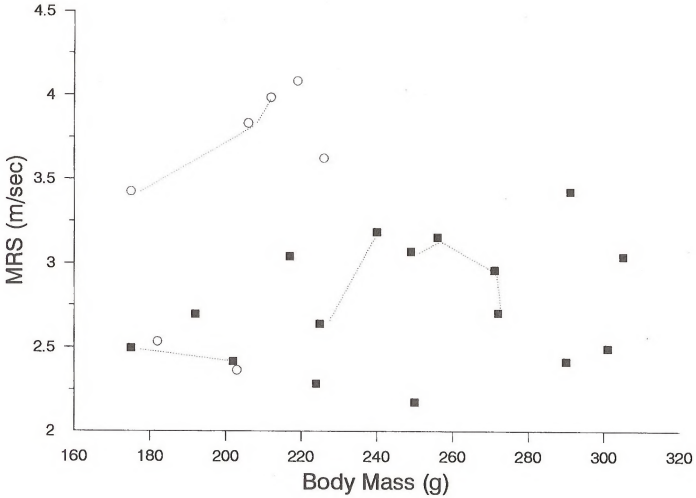

Fig. 6. Relationship between maximum running speed (MRS) and body mass of adult male Townsend's ground squirrels. Open circles denote time trials conducted in 1993, and closed squares denote trials in 1994. Repeated measurements of 4 individuals are connected by dotted lines.

when most (>50%) individuals reached a phenological stage, because these dates are probably most relevant to foraging squirrels. In general, *P. secunda* matured in late March to early April, began withering in early May, and was mostly desiccated by about 20 May (Table 10). *R. testiculatus* matured in late March, began to wither in late April, and was mostly desiccated by early May (Table 10). Phenology patterns for these 2 species were fairly similar between burned and shrub habitats (Table 10), although maturation and withering of *P. secunda* was slightly earlier (<1 week) on burned sites. Phenology of these species in 1994 was different than patterns for 1992 or 1993 (Van Horne et al. 1993*b*). Maturation dates for 1994 were most similar to 1993, whereas desiccation dates for 1994 were most similar to 1992. These trends probably reflect macroclimate patterns. Temperatures were below average and snowfall was above average in early season during both 1994 and 1993, whereas precipitation was below average during mid-season in 1994 and 1992.

Seasonal changes in percent cover of succulent *P. secunda* were consistent with the phenology results (Fig. 7). *P. secunda* coverage increased about 100% from early season to mid season (Fig. 7). Again, this increase was similar to seasonal changes for *P. Secunda* in 1993. By late season, however, there was <0.1% coverage of succulent *P. secunda* (Fig. 7), which corresponds with results from 1992.

Diet

Repeatability of Diet Determination.--Overall, the similarity indexes of diet composition from subsamples of squirrel fecal samples averaged 79.04% (SE= 4.05, n = 24). Similarity varied among habitats and periods (Table 11), however, with a general trend for decreased repeatability later in the year when diets were more diverse (Table 11), especially on burn sites. A Spearman's rank correlation (R_s) indicated a negative relationship between the similarity index and the total number of species in the sample (R_s = -0.76, P = 0.0001, n = 24). Therefore, determining the relative density of items in squirrel diets seems to be repeatable with the microhistological technique, even with only 1 slide per sample, when diets typically contain ≤4 items (Table 11). If diets are more diverse, less confidence should be placed in the relative density of items.

Fecal Analysis.--We were able to obtain only early season diets on the winterfat sites (Fig. 8). As in previous years, *C. lanata* comprised a relatively large portion of the diet on these sites. The early

Table 10. Phenology of *Poa secunda* and *Ranunculus testiculatus* at the Snake River Birds of Prey National Conservation Area, 1994. "Mature" indicates the date that most (>50%) individuals on a site were vegetatively mature and producing reproductive structures. "Withering" refers to when the above-ground biomass of most individuals had begun to desiccate, and "desiccated" refers to when the above-ground biomass of most individuals seemed completely desiccated. Means are presented for multiple sites (n), and the unit for SE's is number of days.

		Mature			Withering			Desiccated		
Species	Habitat	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE
Poa secunda	Burned	10	31 MAR	0.92	9	1 MAY	1.37	8	21 MAY	1
	Shrub	7	6 APR	1.85	6	6 MAY	1.67	6	20 MAY	0.9
Ranunculus testiculatus	Burned	7	30 MAR	0.67	7	25 APR	1.51	6	11 MAY	1.8
	Shrub	4	30 MAR	0.41	4	26 APR	3	4	10 MAY	1.5

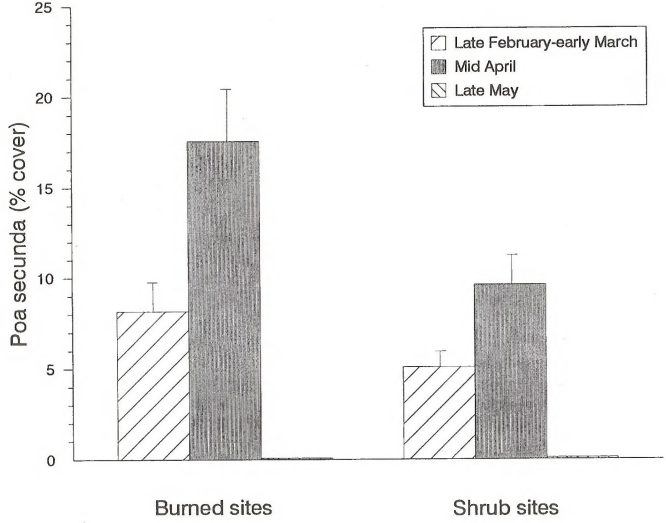

Fig. 7. Percent cover of succulent *Poa secunda*, a major food of Townsend's ground squirrels at the Snake River Birds of Prey National Conservation Area, during 3 sampling periods in 1994. Bars represent means for 10 sites plus 1 SE. The mean percent cover was <0.1% during late May in both habitats.

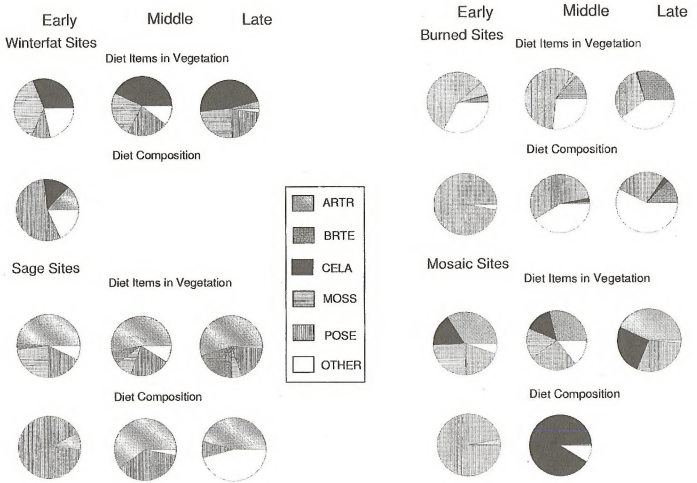

Fig. 8. For each habitat type trapped on the Snake River Birds of Prey Area, and for each sampling period in 1993, percent composition of plant types in feces of Townsend's ground squirrels is averaged across sites. These are compared with relative percent cover on the trapping sites of all plants that appear in ground squirrel diets, sampled during the same time period.

Table 11. Repeatability of determining the diet of Townsend's ground squirrels using the microhistological technique on feces. Similarity indexes (see text) were calculated from 3 subsamples from individual fecal samples (n = 24). The similarity indexes were based on relative densities of diet items determined by the Compositional Analysis Laboratory in a blind test.

			Similarity index (%)		Total no. items[c]	
Period[a]	Habitat[b]	n	$\bar{x}$	SE	$\bar{x}$	Range
1	Burn	3	99.44	0.56	1.33	1 - 2
	Sagebrush	3	80.14	7.91	2.67	2 - 3
	Winterfat	3	79.37	9.25	3.33	2 - 5
2	Burn	3	77.23	9.06	3.00	3 - 3
	Sagebrush	3	89.22	6.45	2.67	2 - 3
	Winterfat	3	90.77	2.66	3.33	2 - 5
3	Burn	3	39.91	10.52	7.67	7 - 9
	Sagebrush	3	76.24	4.68	8.00	6 - 9

[a] Period 1 = 21 February-29 March, Period 2 = 14 April-5 May, Period 3 = 17-25 May.
[b] The winterfat category includes a winterfat-dominated site (1a) and a winterfat-sage mosaic site (3b).
[c] The total number of diet items in a sample.

season diet on sage sites was composed almost entirely of *P. secunda*, whereas the proportion comprised of *A. tridentata* was highest in mid-season. "Other" foods (primarily forbs) increased in importance as the season progressed. Similarly, on burned sites the early season diet was almost entirely *P. secunda*, and the proportion of "Other" (mostly *Salsola ibirica,* grass seed and glume, and *Descurania)* increased through the season. On winterfat/sage mosaic sites the diet changed from being almost entirely *Poa secunda* early in the season (7 samples) to mostly *Ceratoides lanata* at mid-season (10 samples; Fig. 8). *Bromus tectorum* comprised a substantial portion of the diet only on burned sites late in the season (Fig. 8). Overall patterns of difference among sites and between early and late samples are similar to those reported for 1991 (Van Horne et al. 1992) and 1992 (Van Horne et al. 1993b).

Cafeteria Tests.--There were no clear within-season trends in preference (Fig. 9). On 1 occasion near the middle of the experimental period in late April the 3 experimental animals consumed *Artemisia tridentata* preferentially (Fig. 10). *Bromus tectorum* comprised more than 40% of the dry weight consumed during 3 sampling sessions late in the season (Fig. 10).

Across all 39 trials average dry weight consumed was 1.7 g. Animals consumed similar amounts of each of the 4 food types offered (*Poa secunda* $\bar{x}$ = 24 ± 24.1% SD; *Bromus tectorum* $\bar{x}$ = 30 ± 25.4% SD; *Ceratoides lanata* $\bar{x}$ = 24 ± 26.3% SD; *Artemisia tridentata* $\bar{x}$ = 21.4 ± 23.4% SD).

We conclude that animals prefer to mix these food types. We explain the low proportion of *Bromus tectorum* in the diet of free-ranging animals and the sites and times in which a single plant type dominates the diet (Van Horne et al. 1992, 1993b; also see "Fecal Analysis" results above), as resulting from restricted availability of plants in succulent condition.

Forage Quality.--We found a significant difference in the similarity indexes between the March and May sampling periods ($P = 0.0043$), but not between habitat types ($P = 0.9151$). Table 12 shows the indexes calculated by sampling period and habitat type. The overall mean for all sampling periods and habitats was 81.37 ± 5.08% ($\bar{x}$ ± 1 SE) and ranged from 40.84-100%.

Table 12. Similarity indexes calculated for matched pairs of stomach and fecal samples from 17 Townsend's ground squirrels collected in the Snake River Birds of Prey National Conservation Area, Idaho, March-May 1993.

	Similarity Indexes					
	March 1993			May 1993		
Habitat	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE
Sagebrush	6	86.7	8.3	4	72.7	8.8
Burned Sagebrush	4	100.0	.0	3	57.5	8.8
Combined	10	92.0	5.3	7	66.2	6.5

Table 13. Composition of forage removed from stomachs of Townsend's ground squirrels by habitat type and time of year in the Snake River Birds of Prey National Conservation Area, Idaho, 1993.

	March 1993						May 1993					
	Burned Sagebrush			Sagebrush			Burned			Sagebrush		
Component	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE
Cellulose (%)	9	11.38	0.26	5	11.40	0.47	3	13.84	2.45	6	12.47	1.83
Lignin (%)	9	3.31	0.45	5	3.06	0.39	3	5.28	0.66	6	6.67	1.09
Hemicellulose (%)	9	23.46	0.65	5	21.96	0.55	3	14.69	0.97	6	26.42	4.55
Silica (%)	9	2.0	0.35	5	3.61	1.00	3	2.13	0.61	6	1.95	0.66
Protein (%)	9	33.81	0.61	5	36.96	1.76	3	19.75	1.54	6	19.64	2.86
Lipid (%)	9	6.94	0.53	5	8.50	2.38	3	8.02	0.67	6	7.66	1.66
Gross Energy (kcal/g)	9	4.51	0.05	5	4.49	0.07	3	4.27	0.11	6	4.34	0.22

Comparisons of forage quality (Table 13) indicated that there were no significant differences between habitat types within a sampling period, but that protein content decreased significantly from March to May ($P = 0.0061$) and lignin content increased ($P = 0.0319$). Hemicellulose content was calculated as (NDF - ADF) and silica content as (ADF - cellulose - lignin).

ACKNOWLEDGMENTS

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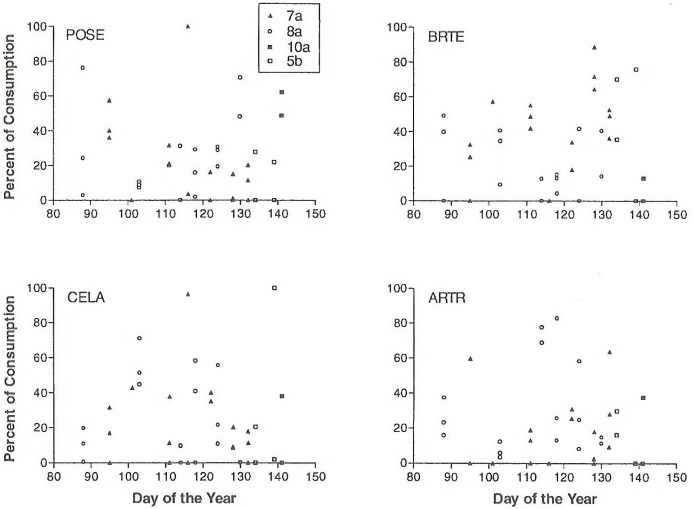

Fig . 9. Dry weight percent of consumption by Townsend's ground squirrels in 1994 cafeteria trials that was *Poa secunda (POSE), Bromus tectorum* (BRTE), *Ceratoides lanata* (CELA), and *Artemisia tridentata* (ARTR) by day of the year on which the trial was held.

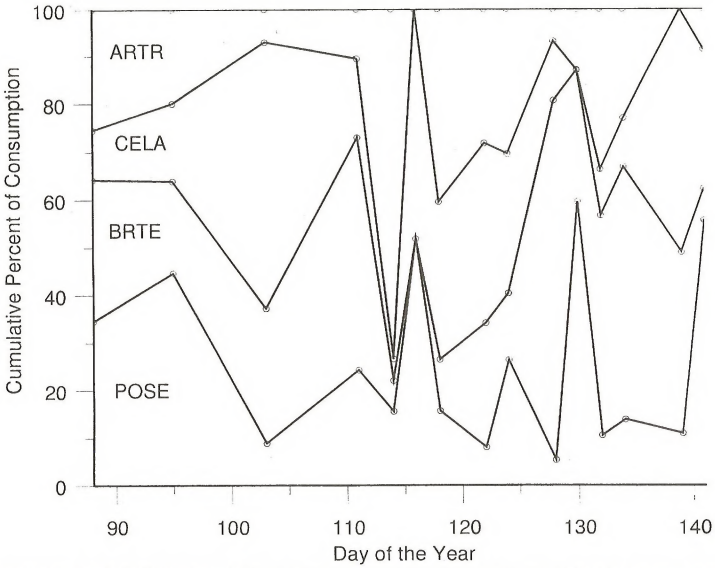

Fig. 10. Mean cumulative dry weight percent consumption of *Poa secunda* (POSE), *Bromus tectorum* (BRTE), *Ceratoides lanata* (CELA), and *Artemisia tridentata* (ARTR) for up to 3 animals subject to cafeteria trials on the same day and site by day of the year.

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Some Processes Influencing Survival of Townsend's Ground Squirrels

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ANNUAL SUMMARY

*Townsend's ground squirrels (**Spermophilus townsendii**) continued to show a pattern of greater size and fattening in sagebrush habitats than in other habitats on the Snake River Birds of Prey Area. Size and large lean mass favored survival of adult males on sagebrush sites over the 1993-94 winter. Food supplementation appeared to allow animals to survive regardless of their condition prior to torpor, and to persist in the habitat when a control population disappeared. Soon after emergence from hibernation, ground squirrels had similar fatty acid composition of adipose tissue on all sites and had unexplained large amounts of eicosanoic acid (20:1) in adipose tissue.*

OBJECTIVES

The objective is to investigate the processes behind observed patterns of survival across habitats, by examining the following questions:

1. How do body mass and body condition (% fat) vary with habitat? How do these attributes influence survival through the torpid period?

2. What is the role of fats in determining body condition, and survival through the torpid period?

3. How does availability of fats in the foods and tissues vary temporally and spatially?

METHODS

Body Mass and Body Condition

Live Animals in the Field.--To assess the effects of body condition on overwinter survival, I examined trapping records for 1994 to determine which of the 69 individuals trapped and examined for body condition on study sites in May 1993 had survived. I compared condition of survivors in May 1993 (total body electrical conductivity analyzer [TOBEC; EmScan model SA-2];see Corn and Van Horne 1991) to that of animals of unknown fate. Comparisons were made by age and sex classes because of differences in size between these groups. I analyzed animals from sites 8a (supplemented

burned/reseeded site) and 8b (unsupplemented control burned/reseeded site) separately, even though mass and body composition of squirrels did not vary between the 2 sites in May 1993, because supplementation could affect survival in other ways than altering condition of animals.

I measured the mass and body composition of ground squirrels with the TOBEC at emergence from hibernation in late February and early March, to determine their condition early in the active season. Study 4 technicians captured animals, and I assessed their body composition during regular livetrapping at 6 sites (4a and b, 5a and b, and 8a and b) from 16 February - 3 March. Sites 8a and b and site 5 were each visited 3 times; the remaining sites were visited 1 time each. I measured mass and body composition of ground squirrels prior to estivation in April and June. In April, adult male ground squirrels were still active, and the field effort focused on characterizing their condition prior to estivation because this sex and age class was poorly represented in late-season sampling efforts in previous years. Five sites were visited (4a, 5a and b, 8a and 9a), each 1 time, except site 5b was visited twice. I visited 4 sites in June (4a, 5a and b, and 8a), with each site sampled once except for site 4 which was sampled twice. Other sites, sampled in previous years, were not sampled due to lack of captures on those sites.

Fat Deposition Patterns.--I measured seasonal variation in the fatty acid composition of ground squirrels from adipose tissue samples of animals collected at emergence and prior to estivation at 2 different times of year (April and June). Ground squirrels were livetrapped adjacent to sites, transported to the field laboratory, euthanized with halothane, and a small sample (0.1 g) of adipose tissue was immediately extracted and placed in 0.9% NaCl, then immediately frozen. Samples were transported frozen to CSU on dry ice. Fatty acids were extracted and characterized as described previously (Van Horne et al. 1992).

Fats in the Diet.--Vegetation samples were collected in April and June to measure sources of fats in the diets of ground squirrels preparing for estivation at 2 different stages in the phenology of the plants. I used the approach described in Van Horne et al. 1993. I separated plant parts of each species immediately after collection and cooled them rapidly by placing them on dry ice in the field. I then transported plants to Colorado State University frozen, and freeze dried them immediately upon arrival at CSU. Extraction and analysis of plant tissues follows Van Horne et al. (1992), and is still in progress.

RESULTS AND DISCUSSION

Body Mass and Body Condition

Overwinter survival.--Survival of ground squirrels for whom body composition prior to hibernation was known varied among age and sex classes and habitats. In some cases condition in May 1993 explained patterns of survival. No juvenile males ($n = 6$) analyzed in the TOBEC in May 1993 were known survivors. Similarly, no adult males ($n = 3$) sampled in May 1993 on site 8b survived; only 2 of 8 adult males survived on 8a (supplemented site); and only 1 of 4 are known to have survived from burned sagebrush sites (Table 1). In contrast, survival of adult males was greater on sage sites, with 5 of 14 animals assessed in the TOBEC captured in 1994. Surviving males on sagebrush sites were larger in May 1993 than animals of unknown fate, with significantly greater lean mass ($t = 2.937$, $P = 0.012$). For other site types, sample sizes were too small for statisical comparisons of May 1993 condition of male survivors and those of unknown fate. Results suggest that larger adult males are more likely to survive overwinter, because adult males tended to be bigger and in better condition on sagebrush sites than on grass sites (Van Horne et al. 1993).

Adult females were known to have survived from all site types sampled with the TOBEC in May 1993, and more individuals survived than did not on all site types (Table 1). On the supplemented site, the only site for which sample size was sufficient for statistical comparison between the 2 groups, there were no differences in size or condition between survivors and those of unknown fate. Supplementation may eliminate the survival advantage of large size or great fat deposition, by allowing most individuals to grow similarly big and fat.

Table 1. Characteristics (in May 1993) of survivors and ground squirrels with unknown fates in the Snake River Birds of Prey Area overwinter 1993-94. Standard errors in parentheses.

Site type	Age/Sex	Fate	*n*	Mass	Lean	Fat	% fat
Burned	Adult male	Survived	1	254.2	194.7	59.5	23.4
		Unknown	3	260.6	191.7	68.9	26.5
				(4.9)	(13.3)	(12.2)	(4.8)
	Adult female	Survived	3	185.3	130.9	54.4	29.6
				(19.6)	(16.1)	(4.5)	(2.0)
		Unknown	1	206.6	140.8	65.8	31.9
	Juvenile female	Survived	1	151.7	135.4	16.3	10.7
		Unknown	4	130.5	106.8	23.7	18.0
				(8.4)	(6.1)	(3.3)	(1.7)
Sagebrush	Adult male	Survived	5	254.9	180.3	74.6	29.1
				(10.0)	(6.1)	(6.3)	(1.6)
		Unknown	9	238.8	163.2	75.6	31.5
				(5.4)	(2.8)	(4.8)	(1.4)
	Adult female	Survived	4	173.2	139.7	33.5	19.6
				(4.5)	(9.9)	(6.1)	(3.9)
		Unknown	2	178.0	125.1	52.9	29.7
				(8.0)	(4.7)	(3.3)	(0.5)
	Juvenile female	Survived	1	109.4	96.8	12.6	11.5
		Unknown	1	110.1	93.4	16.7	15.2
Burned/ Reseeded	Adult female	Survived	1	151.9	124.8	27.1	17.8
		Unknown	1	140.9	105.4	35.5	25.2
Supplement Site	Adult male	Survived	2	231.3	171.7	59.6	25.5
				(17.3)	(3.5)	(13.8)	(4.1)
		Unknown	8	219.4	160.9	58.4	26.8
				(11.1)	(10.1)	(4.7)	(1.9)
	Adult female	Survived	6	153.2	119.3	33.9	21.6
				(7.7)	(2.9)	(5.4)	(2.2)
		Unknown	4	163.1	125.4	37.7	23.0
				(17.4)	(12.3)	(5.2)	(0.9)
	Juvenile female	Survived	1	110.8	94.9	15.9	14.4
		Unknown	1	120.4	105.5	14.9	12.4

On other sites (sagebrush and burned), adult female survivors tended to be smaller than those not recaptured in 1994 (Table 1). Juvenile females were not captured in sufficient numbers to examine survival patterns statistically. Generally, juvenile female survivors were bigger, but not necessarily fatter, tending to have larger lean mass than those of unknown fate (Table 1).

Condition at emergence.--Adults retained about 20% of their body mass as fat through the winter, even after a 2-week period of snow cover soon after emergence from hibernation (Table 2). Condition of ground squirrels may have been reduced from previous years due to the adverse conditions at emergence; this will be explored further in the final report. Overall, there were no significant differences in size and condition of ground squirrels among habitat types at this time of year.

Fattening patterns.--In April, adult males were reaching peak body mass and condition prior to entry into torpor, while adult females were just beginning to fatten after weaning litters (Table 3). At this time of year, males were significantly bigger on sagebrush sites than on burned sites ($t = 2.758$, $P = 0.028$), and were marginally fatter on sagebrush sites than the other two sites ($F = 2.925$, $P = 0.10$). Females, too, had greater lean mass on sagebrush sites than on others for which there was significant sample size for comparison (the supplemented site; $t = 2.229$, $P = 0.043$). The fattening period for juveniles and females was brief; sample sizes were not sufficient for statistical comparisons among groups in early June because most animals had disappeared from the trappable population by this time.

Table 2. Mass and body composition of adult Townsend's ground squirrels in the Snake River Birds of Prey Area soon after they emerged from hibernation in 1994. Standard errors in parentheses.

Site type	*n*	Mass	Lean	Fat	% Fat
Burned-males	4	166.3 (11.2)	126.8 (7.2)	39.5 (4.9)	23.5 (1.7)
Burned-females	2	151.4 (30.6)	134.5 (26.5)	16.9 (4.1)	11.1 (0.5)
Burned, reseeded-males	4	141.9 (17.6)	111.1 (10.0)	30.8 (8.6)	20.7 (3.4)
Burned, reseeded-females	4	131.2 (19.1)	115.9 (23.1)	18.1 (9.4)	14.2 (5.8)
Supplemented-males	6	161.2 (7.2)	121.4 (5.5)	39.8 (3.0)	24.6 (1.4)
Supplemented-females	13	124.2 (5.7)	99.3 (3.2)	24.9 (3.4)	19.1 (2.1)
Sagebrush-males	5	166.0 (9.2)	131.3 (5.5)	34.7 (4.6)	20.6 (1.8)
Sagebrush-females	5	129.5 (9.7)	104.1 (9.4)	25.4 (1.1)	19.9 (1.4)

Table 3. Mass (g) and body composition of Townsend's ground squirrels in the Snake River Birds of Prey Area in April and June 1994. Standard errors in parentheses.

Age/Sex-Month	Site type	*n*	Mass (SE)	Lean (SE)	Fat (SE)	% Fat
Adult male-April	Burned	3	240.5 (16.3)	161.8 (8.8)	78.7 (10.2)	32.5 (2.6)
	Supplemented	4	262.9 (15.9)	179.1 (8.0)	83.8 (9.8)	31.6 (2.3)
	Sagebrush	6	300.3 (12.9)	186.2 (10.6)	114.1 (11.7)	37.8 (2.9)
Adult female-April	Burned	2	181.4 (16.3)	163.1 (24.9)	18.3 (8.6)	10.6 (5.7)
	Supplemented	7	168.8 (11.8)	121.9 (6.2)	46.8 (7.4)	26.9 (2.9)
	Sagebrush	9	177.2 (6.7)	139.5 (5.0)	37.7 (5.6)	21.0 (2.6)
Adult females-June	Burned	1	159.3	117.5	67.3	36.4
Juv. male-April	Supplemented	1	129.9	111.9	18.0	13.9
Juv. male-June	Burned	2	185.4 (8.2)	127.4 (16.1)	87.9 (33.4)	39.3 (6.5)
	Supplemented	2	168.0 (9.0)	118.9 (0.2)	70.4 (0.5)	37.1 (0.1)
	Sagebrush	1	142.4	98.6	28.0	22.2
Juv. female-June	Supplemented	2	168.0 (9.0)	118.9 (0.2)	70.4 (0.5)	37.2 (0.1)
	Sagebrush	2	133.8 (15.2)	107.3 (6.0)	46.1 (12.6)	29.5 (4.6)

Fat Deposition Patterns.--No significant differences were found in the adipose tissue fatty acid composition of ground squirrels from sagebrush or burned sagebrush sites in late February and early March, as soon as activity resumed after the late winter snow storm (Table 4). The most striking aspect of the fatty acid profiles of ground squirrels' adipose tissue at this time, unrelated to sex or habitat, was the large amounts of 20:1 (eicosanoic acid) found. This inexplicable pattern has only been found in animals with severe EFA (essential fatty acid; 18:2 [linoleic acid] and 18:3 [linolenic acid]) deficiency (M. Harris, Dep. of Foods and Nutrition, Colorado State University, pers. commun.) The spring snowstorm may have represented a period of EFA deficiency for euthermic ground squirrels, but adipose tissue contained large amounts of both 18:2 and 18:3. Indeed, when the February/March and June adipose tissue analyses each were pooled and compared statistically, the early season group had a higher percentage of linolenic acid than the late season group ($t = 2.532$, $P = 0.024$), and there was no difference in percent composition of linoleic acid between the 2 periods. Sample sizes were too small for statistical comparisons between habitats in April or May (Table 5).

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Table 4. Fatty acid composition of Townsend's ground squirrels collected from the Snake River Birds of Prey Area in February and March 1994.

	Burned Sites			Supplemented Site			Burned/ reseed Site	Sagebrush Sites		
Fatty Acid[a]	$\bar{x}$	SE	n	$\bar{x}$	SE	n	(n=1)	$\bar{x}$	SE	n
12:0	0.82	0.1	3	0.91	0.28	4	1.32	0.67	0.07	3
14:0	0.47	0.3	3	0.54	0.42	2	0.49	0.16	0.02	3
16:0	11.45	2.7	3	9.67	0.29	4	18.05	10.74	0.93	3
16:1	1.06	0.2	3	1.46	0.31	4	1.88	1.97	0.32	3
17:0	0.37	0.2	2	0.31	0.09	2	0.42	0.38	0.07	3
17:1	2.25	2.1	2	0.31	0.04	3	0.44	0.38	0.05	3
18:0	3.46	0.6	3	3.09	0.82	4	2.91	2.22	0.46	3
18:1	32.54	2.2	3	34.8	4.97	4	24.84	37.81	2.03	3
18:2	15.11	0.6	3	16.7	1.87	4	11.77	18.61	5.22	3
18:3	16.2	5.5	3	16.3	2.38	4	35.79	19.4	3.18	3
20:0	1.71	0.8	2	0.64	0.26	4	-	0.27	0.13	3
20:1	9.41	4.6	3	8.25	0.94	4	0.21	4.03	0.45	3
20.4	1.11	0.2	3	1	0.3	4	0.59	0.41	0.11	3
22:6	-	-	0	0.75	0.24	3	-	0.36	0.15	3

[a]Number of carbons in fatty acid carbon chain : number of double bonds

Table 5. Fatty acid composition of Townsend's ground squirrels collected from burned sites and sagebrush sites on the Snake River Birds of Prey Area in April and June 1994.

	April Burned Site	June Burned Sites			April Sagebrush Site	June Sagebrush Sites		
Fatty Acid[a]	(*n*=1)	$\bar{x}$	SE	*n*	(*n*=1)	$\bar{x}$	SE	*n*
12:0	1.28	0.87	0.07	3	1.13	1.14	0.06	2
14:0	0.32	0.23	0.03	3	0.34	0.23	0.01	2
16:0	18.96	14.52	0.75	3	19.77	17.10	0.73	2
16:1	2.98	2.78	0.16	3	2.36	1.87	0.44	2
17:0	0.36	0.72	0.05	3	0.36	0.35	0.01	2
17:1	0.58	0.87	0.09	3	0.50	0.44	0.03	2
18:0	1.80	2.47	0.10	3	1.92	2.20	0.21	2
18:1	43.59	55.18	2.30	3	45.32	42.10	3.74	2
18:2	7.12	11.38	0.25	3	7.50	20.31	2.72	2
18:3	21.57	7.67	1.01	3	18.77	11.98	1.72	2
20:0	0	0.50	0.002	2	0.14	-	-	0
20:1	0.32	0.86	0.17	3	0.40	1.13	0.45	2
20:4	0.34	0.20	0.04	3	0.17	0.30	0.16	2
22:6	0.25	0.20	0.08	2	0.26	0.24	0.13	2

[a]Number of carbons in fatty acid carbon chain : number of double bonds

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Behavior of Townsend's Ground Squirrels in Different Habitat Types

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ANNUAL SUMMARY

*During the final field season (January-June 1994) of the planned 4-yr study we continued to collect information that will help us describe behavioral differences among habitat types for Townsend's ground squirrels (**Spermophilus townsendii**). We collected behavioral data on 4 study sites that differ in vegetation type, fire history, and history of tracking by armored vehicles. No significant differences were detected in the amount of time spent in burrows, walking, vigilant, or foraging by the ground squirrels among the 4 sites. Experimental tracking by armored vehicles had no detectable short-term effect on observed behavior.*

We quantified an index of predator detection in each habitat type. We found that ground squirrels in burned sagebrush habitats can detect predators at a greater distance, and those in sagebrush/winterfat mosaic at a lesser distance, than ground squirrels in the other habitat types. We also conducted an intensive fluorescent powder study near the northern boundary of Site 8a to determine patterns of burrow use, burrow sharing, and home range sizes.

OBJECTIVES

1. To determine whether Townsend's ground squirrel behavior differs:
   a) among age or sex classes,
   b) among habitat types,
   c) between burned and unburned areas,

d) between areas that have been recently tracked by armored vehicles and those that have not.

2. To understand the role that microclimate plays in influencing Townsend's ground squirrel behavior.

3. To describe how aspects of burrow morphology and burrow use by ground squirrels vary among habitats, and to evaluate the usefulness of burrow entrances as indicators of Townsend's ground squirrel density.

METHODS

Study Sites

We observed behavior on 4 sites representing different habitat types, fire history, and armored vehicle tracking history. These include sites 4a, 5b, 9b, and 10a in Table 1 of Van Horne et al. (this volume). Figure 1 of that report shows site locations. Sites 1a and 3b were not included in this season's observations because there were few or no captures of ground squirrels on these sites.

Behavioral Observations

Activity Budgets.--We (usually P. B. Sharpe and D. DiMauro [technician]) collected data on Townsend's ground squirrel behavior from 7 February through 14 June 1994. Most observations were made on ground squirrels that had been uniquely marked with hair dye (Clairol Nice 'n Easy® blue-black) on the 4 sites described above. We often recorded observations of juveniles of unknown sex when marked individuals were not detected.

We observed behavior from a portable 3-m hunter's stand (Hunter's Equipment, Inc., San Angelo, TX) using a 15-60 zoom spotting scope mounted on the stand's railing. We recorded the focal animal's behavior, distance to cover, distance to the most recently used burrow (if known), and distance moved at 20-sec intervals, on a Polycorder electronic notebook (Omnidata International, Inc., Logan, UT). At the beginning of each observation period and at 15-min intervals thereafter, we also recorded temperature, wind speed, and percent cloud cover. We observed each focal animal for a minimum of 10 min per day and a maximum of 30 min per day. We discontinued observations if the focal animal disappeared into the burrow for >5 min or was out of sight for >3 min. If 30 min of observations were not collected for a focal animal, we attempted to relocate the individual during the day for further observations. We assessed relative predation pressure from raptors by recording the number and species (if known) of raptors seen flying over the site during each 15-min interval. Additional observations or comments were recorded on a microcassette for later transcription.

To be able to pool behavior data from the different observers we had to test for observer agreement. This was accomplished by simultaneously recording behavior on individual ground squirrels and comparing observations between observers. This calibration was conducted in late February/early March and late May.

We summarized mean proportions of time spent in each activity for each animal, and these were arcsine-transformed prior to analysis. Only observations in which the animal was visible were included in calculations. When testing for age or sex differences, each sample point represented the mean value for a single animal of known age or sex. We used data from all observed animals when comparing sites or site types. We used ANOVA to test for differences among site, site type, age, and sex classes. Significant ANOVA's were investigated using Tukey's Studentized Range Test.

Environmental Factors. -- We measured temperature, wind speed, relative humidity, and solar and thermal radiation throughout the day in conjunction with the behavioral observations to identify relationships between environmental conditions and ground squirrel activity. All equipment was obtained from Campbell Scientific, Inc., Logan, UT as described in Van Horne et al. (1992).

In addition to the weather equipment, we used hollow bronze mounts of ground squirrels covered

with a ground squirrel pelt to measure the true environmental temperature (T_e) described in Sharpe and Van Horne (1993).

Habitat Manipulation Experiment

To determine the effects of shrub cover on ground squirrel behavior, we moved previously constructed artificial shrubs to a burned sagebrush site (Site 8a). These were designed to provide cover and obstruct the ground squirrels' vision, but had no forage value. They consisted of a chicken wire basket with a diameter of 60 cm and height of 61 cm (approximate volume of 1,782 dm^3) filled primarily with tumbleweed (*Sisymbrium altissimum*) and Russian thistle (*Salsola iberica*). We placed the artificial shrubs on a 36 X 40 m grid at 4-m intervals, and placed an additional shrub haphazardly within each resulting grid section to break up any visual corridors (200 total shrubs). These shrubs provided the same approximate volume of shrubs found on the OTA sagebrush sites (about 200 dm^3/m^2) when we included a 2-m border around the grid. We then staked out another 36 X 40 m area as a control area. During the same time period, observers watched 2 separate plots and recorded behavior of marked ground squirrels that entered the plots or were within the 2-m border.

Detection Index

We determined an index of how far ground squirrels could detect approaching predators from different postures using a pole with wooden forms representing common predators of ground squirrels. We represented weasels and snakes by a 5 X 5 cm square resting on the ground, badgers or coyotes by a 30 X 30 cm square 20 cm above the ground, and northern harriers by 1 X 0.1 m rectangles 1.5, 2.5, and 4.0 m above the ground. We randomly selected 10 points within each of 6 sites to determine detection distances (random bearings and distances off poles 12-14). From the selected point, we extended a 100-m tape along the same bearing, and 1 person slowly moved the pole with the predator forms along the tape. P. B. Sharpe viewed the pole from 5, 13, and 18 cm above the ground (heights representative of the eye height of a ground squirrel in a standing (4 feet on the ground), sitting, and upright or "picket pin" posture) through holes drilled in a small board. We recorded the maximum distance at which each form was detected from each viewing height. Detection distances >200 m (common in burned sagebrush habitats) were truncated to 200 m.

Shrub Cover and Escape Time from Predators

Risk of predation can be divided into several components, some of which may differ among habitats. One component of predation risk for a desert rodent, such as Townsend's ground squirrels, is escape time to a refuge (burrow) after detection of a predator that is a potential threat. We were interested in how shrub cover might influence escape time. Shrubs are generally considered as beneficial to desert rodents in terms of predation risk, because shrubs can provide concealment cover (Thompson 1982, Kotler 1984). There is a possible tradeoff, however, in that shrubs might also increase escape time to a refuge when an individual is detected by a predator.

We conducted a field experiment with juvenile Townsend's ground squirrels to test this hypothesis. We used juveniles that were of the age and body size of potential dispersers from natal areas, and thus our experiment simulated a situation in which a dispersing juvenile might encounter a predator while exploring novel habitat patches. Specifically, we compared escape times of juveniles in an open area without any shrubs to an area dominated by winterfat shrubs. Our approach was to conduct time trials of maximum running speed on running tracks established in the field. We have previously described the general design of this approach for assessing running speed of ground squirrels (Van Horne et al., this volume), so herein we will only include changes that were made to this design.

We conducted the experiment from 18 May to 5 June 1994 in an area near Site 8a. We erected 2 running tracks, which were 1.0 m wide. Track 1 was in an open area with no shrubs. We removed all vegetation (grasses and forbs) on this track to reduce variation due to spatial and temporal changes in the plant cover. Therefore, Track 1 was a

compact dirt substrate. Track 2 was in a patch of native winterfat. Again, we removed all non-shrub vegetation from this track, so that the only difference between the 2 tracks was the presence of winterfat shrubs on Track 2. Both tracks were flat (<1 degree mean deviation from level based on 10 measurements at 1-m intervals). We marked 3 distances on each track: start (0 m), middle (5 m), and finish (10 m). On Track 2, the structural characteristics of the winterfat shrubs were similar on the 0-5 m and the 5-10 m splits (Table 1).

We captured squirrels, determined their sex and body mass, and marked them with black hair dye. Each individual was tested only once. We used a between-subjects design to test for habitat effects on escape time. Individuals were randomly assigned to either the open or the shrub track. When possible, we paired captured individuals by body mass and sex, and then randomly assigned the members of the pair. We alternated runs between the 2 tracks within a day. We used a within-subjects design to test for distance effects on escape time by recording times for each individual for the 0-5 m split and the 5-10 m split. To encourage the squirrels to run at full speed, we used a domesticated dog and 1 human chaser (Van Horne et al., this volume). One person timed both split times for all trials with hand-held stopwatches while he was seated in a hunter's stand 3-m above the ground. All squirrels were run in the same direction on both tracks.

Our preliminary analyses focused on the effects of habitat on escape time, and therefore we used total time (0-10 m) for these analyses. We used an analysis of covariance to test for effects of habitat, sex, habitat*sex, body mass, and time of day.

Burrow Use

To describe burrow use we conducted a study using fluorescent powder. Ground squirrels were captured away from the normal study sites but in similar habitat, marked with hair dye for later recognition, placed into a plastic bag containing fluorescent powder (Radiant Colors, Inc.), covered completely, and released at the point of capture. We recorded the color of powder applied and time of release. After dark on the same day we returned to the areas and followed the resultant fluorescent trails using a Raytech rechargeable UV lamp (Model R5-FLS). We tagged any burrow entrances that the powdered ground squirrel entered completely with a unique consecutive number for the particular site. If the hole had been used previously by another powdered animal, we recorded the original number to indicate sharing of burrows. We also measured the distance of the powder trail in many cases by laying a 100-m tape along the trail. This study was conducted most intensively on a 75 x 150 m site north of Site 8a because ground squirrel densities were higher in

Table 1. Characteristics of winterfat shrubs on a running track used to measure the escape time of juvenile Townsend's ground squirrels. Data are presented for each half of the track.

		Max. height (cm)		Max. width (cm)*		Density
Split	n	$\bar{x}$	SD	$\bar{x}$	SD	(no./m^2)
0-5	31	15	5.18	16.97	8.03	6.2
5-10	38	14.58	5.09	16.74	7.83	7.6

*The maximum width was measured perpendicular to the path that the squirrels ran.

this area than at most of the remaining sites. A sample of the tagged burrow entrances on this site also were smoked to determine the number of entrances/burrow system and the maximum linear length between entrances.

RESULTS AND DISCUSSION

Observer Agreement.--We observed 7 squirrels during each of 2 periods (28 February-13 March and 5 May-8 May) to compare behavior records between observers. During the first period, the percentage of observations in which the same code was used was 78.8 $\pm$ 9.1% ($\bar{x} \pm 1$ SD), and the percentage of observations with the same general category (ie. foraging, vigilant) was 93.5 $\pm$ 4.6%. During the second period, observations with the same code and same general category were 64.0 $\pm$ 9.2% and 92.0 $\pm$ 4.8%, respectively. Most of the differences in recorded observations were in foraging categories where 1 observer would record a specific forage item, while the other would record an unknown item. This can easily result when the observers do not have the same viewing angle of the focal animal. Table 2 shows the results of the behavioral observations for the 2 most common activities: foraging and vigilance. Across all calibration observations, D. DiMauro recorded mean values of 19.8 and 49.2 for vigilance and foraging, respectively, while P. Sharpe recorded mean values of 17.5 and 51.27. We are confident that pooling the data from the 2 observers had no significant effects on the results because of the relatively high agreement between observers and a much higher proportion of recorded observations being made by P. Sharpe.

Activity Budgets.--We recorded 66.2 hrs of behavioral observations during 415 observer hrs in the stands on the behavior sites described above. In addition, we collected 8.4 hrs of data on Site 8a during training of observers which are not included in these analyses. In our analysis, we used only activities that comprised >5% of the mean of observation strings across all animals. We grouped these activities into 4 major categories: "in burrow," "walking," "vigilant," and "foraging." "In burrow" was the proportion of time in which ground squirrels were underground while active. "Walking" was the proportion of time spent in locomotion (minus running, which represented a very small proportion of activity on most sites). "Vigilant" represented the proportion of time in which ground squirrels were alert and was composed of the time spent sitting on haunches (not including time spent sitting and eating), standing in the upright (picket pin) position, standing on all 4 legs with head raised, or standing/sitting in a shrub (not eating or climbing). "Foraging" included eating of any food type.

We calculated an ANOVA with multiple effects for each major activity. We found no significant differences for the overall model for any of the 4 categories of behavior ($P > 0.1303$). However, there was a significant site effect ($P = 0.0306$) and age*site interaction ($P = 0.0277$) for foraging.

Age and Sex.--We combined all animals within sites because we found no significant differences in the amount of time spent in different activities between age classes ($P > 0.4211$) or sex classes ($P > 0.4470$). We could not test for age differences on Site 9b because no juveniles were observed.

Habitat.--The ANOVA indicated a slightly significant site difference ($P = 0.0306$) in the proportion of time spent foraging among sites. However, Tukey's Studentized Range Test identified no pairwise differences. As in 1992 and 1993, sites within habitat types did not differ significantly in the proportion of time spent in each activity (Table 3), so sites in similar habitats also were combined. There were no significant differences between habitat types in the amount of time spent in various activities, although only burned sagebrush and OTA sagebrush sites were observed this season (Table 4).

Environmental Factors. -- Analyses of relationships between environmental factors and activity patterns of the ground squirrels will be made for the final report.

Habitat Manipulation Experiment

We were able to watch an average of fewer than 4 ground squirrels per day on either the control or treatment plots this season, even though we placed the plots on one of the most highly populated sites.

Table 2. Similarity of behavioral observations by D. DiMauro and P. Sharpe. Observations of ground squirrels were made on burned sagebrush sites (8a and 10a) and an OTA sagebrush site (5b) in the Snake River Birds of Prey National Conservation Area, Idaho, 1994. Calibrations were made at the beginning of the season (28 February - 13 March) and near the end of the season (5-8 May). The percent of time spent foraging and vigilant as recorded by the 2 observers and the percent of observations that were in agreement (either identical or the same category (i.e., foraging, vigilant)) between the 2 observers are reported.

		DiMauro		Sharpe		
Squirrel	No obs[a]	% Forage	% Vigilant	% Forage	% Vigilant	% Agreement
28 Feb-13 Mar 1994						
1	9	9.0	18.2	9.0	9.0	88.9
2	40	95.0	2.5	95.0	0.0	90.0
3	33	68.8	21.9	68.8	21.9	100.0
4	26	61.5	38.5	61.5	38.5	100.0
5	25	80.0	16.0	88.0	8.0	92.0
6	11	18.0	27.0	18.0	18.0	90.9
7	53	15.1	75.5	20.8	69.8	92.5
	Mean Value	49.6	28.5	51.6	23.6	93.5
5-8 May 1994 1994						
1	38	57.1	6.3	60.3	3.2	92.1
2	46	71.4	1.4	71.4	1.4	93.5
3	23	62.5	3.1	75.0	0.0	91.3
4	28	37.1	45.7	25.7	51.4	85.7
5	23	43.8	9.4	37.5	12.5	87.0
6	18	20.0	10.0	23.3	10.0	94.4
7	29	20.0	10.0	23.3	10.0	100.0
	Mean Value	48.8	11.1	51.0	11.4	92.0

[a] Number of recorded behavioral observations made for each individual.

Table 3. Major activities by site of Townsend's ground squirrels in the Snake River Birds of Prey National Conservation Area, Idaho, 1994. All squirrels are grouped for each site. Reported values are the percentage of time observed in each activity.

	Activity															
	In Burrow				Walking				Vigilant				Foraging			
Site	*n*	x̄	SE		*n*	x̄	SE		*n*	x̄	SE		*n*	x̄	SE	
4a	20	7.3	1.9	A[a]	2	5.5	1.1	A	20	25.7	5.4	A	20	54.	6.	A
10a	38	6.6	0.6	A	3	6.6	0.6	A	38	22.9	3.5	A	38	51.	3.	A
5b	21	10.7	4.6	A	2	6.8	1.0	A	21	21.0	5.0	A	21	51.	5.	A
9b	17	5.0	2.2	A	1	5.3	0.8	A	17	17.1	4.6	A	17	60.	6.	A

[a] Tukey's Studentized Range Test. Column values with same letter do not differ significantly at alpha=0.05.

Table 4. Major activities by site type of Townsend's ground squirrels in the Snake River Birds of Prey National Conservation Area, Idaho, 1994. All squirrels are grouped for each site type and percent of time spent in each activity is reported.

	Activity															
	In Burrow				Walking				Vigilant				Foraging			
Site Type	*n*	x̄	SE		*n*	x̄	SE		*n*	x̄	SE		*n*	x̄	SE	
Burned Sagebrush	58	6.9	1.4	A[a]	58	6.2	0.6	A	58	23.9	2.9	A	58	52.6	3.3	A
OTA Sagebrush	38	8.1	2.8	A	38	6.1	0.6	A	38	19.3	3.4	A	38	55.5	4.1	A

[a] Tukey's Studentized Range Test. Column values with same letter do not differ significantly at alpha=0.05.

We were therefore unable to detect any significant differences between ground squirrel activity on the 2 plots if differences did exist. Two complete cross-over experiments were conducted, and there were no significant differences between levels of vigilance or foraging between the control and treatment plots in either experiment ($P > 0.0948$). We looked at activity levels of individuals observed in a plot with and without added cover and there did not seem to be any consistent changes in behavior (i.e., increased vigilance when cover was added). This may not be too surprising because activity patterns did not differ between burned sagebrush and OTA sagebrush sites this season either. This is proably because the amount of cover on burned sites was high, relative to other years (see below).

Detection Index

Estimated detection distances in this season's index were highly variable, especially for the predator forms at the top of the pole. An ANOVA indicated that sites could be combined by site type for all viewing heights and predator heights, except for the picket pin view (13 cm) of the 2.5-m predator form on the burned sagebrush sites (sites 4a and 10a).

Detection distances in the burned sagebrush habitats were consistently farther than in any other habitat type from all viewing heights and for all predator forms, except the 5-cm viewing height of the 5-cm high predator form. These detection distances in the burned sagebrush habitat were significantly farther than in the mosaic and OTA sagebrush sites in most cases, whereas the winterfat site only differed from the burned sagebrush sites in 2 cases (Table 5). This lack of differences between the burned sagebrush and winterfat sites is probably a result of high densities of dried vegetation on the burned sagebrush sites (i.e., Russian thistle, tansymustards [*Descurainia* spp.]). This vegetation grew during the wet 1993 season, but did not break down during the winter, possibly because of little snowfall. Instead, this vegetation remained on the sites throughout most of the 1994 season.

Predation

Occurrences of raptors on our sites during behavioral observations were relatively rare during 1994. Estimated mean predation pressure in 1994 ranged from a low of 0.03 raptors/15 min period (0.12 raptors/hr) on Site 4a to a high of 0.7 raptors/15 min period (0.28 raptors/hour) on Site 10a (Table 6). There were no significant differences in predation pressure among the 4 sites ($P = 0.3800$).

We observed northern harriers (*Circus cyaneus*) more often than the other diurnal raptors above shrub-dominated habitats. The prairie falcon (*Falco mexicanus*) was the most common raptor above the more open burned sagebrush habitats (Table 7).

Shrub Cover and Escape Time from Predators

We conducted time trials for 32 individual juveniles (16 in each habitat). Our random assignment procedure resulted in similar distributions of body mass for individuals tested in the open habitat ($\bar{x}$ = 160.2 g, range: 104-232) and in the shrub habitat ($\bar{x}$ = 158.1 g, range: 95-229). The distribution of sexes was unbalanced, however, as 7 of the 16 squirrels were females in the open habitat, but 12 of 16 were females in the shrub habitat.

Escape time (sec/10 m) was influenced by habitat and sex, but the habitat*sex interaction was insignificant (Fig. 1, Table 8). Body mass and time of day were not significant covariates (Table 8). Escape time was less in the open habitat than in the shrub habitat, and escape time was less for males than for females. The greatest difference in means between groups was >2 sec (males-open: $\bar{x}$ = 3.47, SD = 0.71, n = 9; females-shrub: $\bar{x}$ = 5.70, SD = 0.83, n = 12). Therefore, our experiment provided support for the hypothesis that shrub cover can increase at least 1 component of predation risk by increasing escape time to a refuge.

Burrow Use

We were able to follow 99 fluorescent trails from 49 ground squirrels in burned sagebrush habitats. Thirty-nine of these squirrels (83 trails) were followed in a single area north of site 8a and will therefore be the primary area of discussion. Ground squirrels in this area used

Table 5. Comparison of estimated detection distances of predators by Townsend's ground squirrels in the Snake River Birds of Prey National Conservation Area, Idaho, 1994.

	Habitat Type															
	Burned Sagebrush				Winterfat				OTA Sagebrush				Mosaic			
Posture	*n*	x̄	SE		*n*	x̄	SE		*n*	x	SE		*n*	x	SE	
0.05 m[a]																
Stand	20	2	0.3	A[b]	10	1.8	0.3	A	20	3	0.4	A	10	1.9	0.4	A
Sit	20	3.3	0.4	A	10	2.6	0.3	A	20	3	0.4	A	10	2.9	0.8	A
Picket	20	3.6	0.5	A	10	2.7	0.3	A	20	4	0.4	A	10	2.7	0.5	A
0.5 m																
Stand	20	15.8	1.5	A	10	11	1.4	AB	20	10	1.4	B	10	6.8	0.7	B
Sit	20	31.3	3.1	A	10	18	1.6	B	20	12	1.5	B	10	9.6	0.7	B
Picket	20	48.1	5.8	A	10	24	2.3	B	20	14	1.7	B	10	11	1.1	B
1.5 m																
Stand	20	42.7	5.3	A	10	29	3.6	AB	20	27	3.8	B	10	17	1.6	B
Sit	20	88.9	9.9	A	10	59	8	AB	20	38	4.5	B	10	25	2.5	B
Picket	20	110.3	10.8	A	10	80	9.4	AB	20	46	6	BC	10	29	4.1	C
2.5 m																
Stand	20	66.4	8.4	A	10	50	5.2	AB	20	43	6.1	AB	10	27	2.7	B
Sit	20	127.7	10.5	A	10	97	11	AB	20	62	7.1	BC	10	37	3.9	C
Picket	20	152.0[c]	9.7	0	10	128	13.1	A	20	78	9.6	B	10	46	7.5	B
4.0 m																
Stand	20	93.9	9.7	A	10	74	7.3	AB	20	64	9.3	AB	10	38	4.2	B
Sit	20	164.1	9.6	A	10	142	12.3	A	20	88	9.3	B	10	55	6.6	B
Picket	20	184.7	7.5	A	10	164	11.2	A	20	10	12.2	B	10	64	8.4	C

[a] Height of predator form.
[b] Tukey's Studentized Range Test. Row values with same letter do not differ significantly at alpha=0.05.
[c] Mean for burned sagebrush, but not used in analysis because there was a significant difference between sites 4a and 10a.

Table 6. Number of raptors observed on Townsend's ground squirrel behavioral sites during 15-min scan samples in the Snake River Birds of Prey National Conservation Area, Idaho, 1994.

	# of Raptors/15 min			
Site	*n*	$\bar{x}$	SE	
4a	150	0.03	0.01	A[a]
10a	130	0.07	0.06	A
5b	161	0.06	0.02	A
9b	95	0.04	0.02	A

[a] Tukey's Studentized Range Test. Column values with same letter within year classes do not differ significantly at alpha=0.05.

Table 7. Number of raptors detected by species over established 9 ha sites during behavioral observations, February-June 1994, in the Snake River Birds of Prey National Conservation Area, Idaho. The percentage of total raptors observed at each site is in parentheses.

	Species[a]					
Site	*C. c*	*B. j.*	*B. l*	*A. c.*	*F. m.*	Unknown
4a	0 (0%)	0 (0%)	1 (25.0%)	0 (0%)	3 (75.0%)	0 (0%)
10a	3 (33.0%)	1 (11.0%)	1 (11.0%)	0 (0%)	3 (33.0%)	1 (11.0%)
5b	8 (89.0%)	1 (11.0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
9b	1 (25.0%)	0 (0%)	0 (0%)	1 (25.0%)	2 (50.0%)	0 (0%)

[a] *C. c.* = *Circus cyaneus* (northern harrier),
B. j. = *Buteo jamaicensis* (red-tailed hawk),
B. l. = *B. lagopus* (rough-legged hawk),
A. c. = *Aquila chrysaetos* (golden eagle),
F. m. = *Falco mexicanus* (prairie falcon).

Fig. 1. Escape time of juvenile Townsend's ground squirrels in open and shrub habitats. Times are from a field experiment with 16 individuals in each habitat. The circles denote females and the squares denote males.

Table 8. Analysis of covariance of escape time (sec/10 m) of juvenile Townsend's ground squirrels.

Source of variation	df	ss	P
Habitat	1	14.15	0.0001
Sex	1	3.31	0.0338
Habitat*sex	1	1.92	0.0997
Body mass	1	0.05	0.7788
Time of day	1	0.02	0.8670
Error	26	17.16	

2.76 ± 0.23 burrow entrances/trail (n = 83, $\bar{x}$ ± 1 SE). The mean trail length was 34.04 ± 4.00 m/trail (n = 53, $\bar{x}$ ± 1 SE). Trails followed generally represent a short portion of daily activity as determined by recaptures of powdered ground squirrels within 1-2 hours of initial release. The trails rarely could be followed to the point of recapture. We were also able to estimate the minimum mean number of individuals using a single hole from the fluorescent tracking data. In the area north of site 8a we found the mean number of individuals using a hole to be 1.19 ± 0.04 ($\bar{x}$ ± 1 SE, n=183).

In the area north of site 8a we mapped the locations of all the burrow entrances that we tagged and could relocate (174 of 183 tagged burrow entrances, 95.1%). Most of the burrow entrances that we were unable to locate were assumed to have been destroyed by badgers. Of the 174 tags relocated, 164 (94.3%) still had burrow entrances present. We smoked 32 burrows (burrows 5, 10, 15, ...) on 8-9 June 1994. The number of entrances per burrow system that we considered useable by ground squirrels was 1.97 ± 0.23 ($\bar{x}$ ± 1 SE, n =32). The maximum linear length between entrances within burrow systems with ≥2 entrances was 1.35 ± 0.18 m ($\bar{x}$ ± 1 SE, n =17). Most burrows had only 1 or 2 entrances (46.9% and 28.1%, respectively). These values are similar to those found in burned sagebrush areas in 1992 (Tables 11-12, Van Horne et al. 1992).

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The Parasite Community of Townsend's Ground Squirrels

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ANNUAL SUMMARY

*We analyzed 916 fecal samples collected from Townsend's ground squirrels (**Spermophilus townsendii**) between February and May, 1994. We found the same 7 species of eimerian as in 1992 and 1993. There was no difference between prevalence of infection in males vs. females, but prevalence of infection was significantly higher in adults than juveniles for **Eimeria callospermophili, Eimeria adaensis**, and all eimerians combined. The prevalence of 4 eimerians was significantly different than previous years. The pattern of infection for all eimerians combined over the entire active season was different in 1994 than other years. Patterns for the 3 most common species (**E. callospermophili, E. adaensis,** and **E. morainensis**) were more stable with respect to each other than in previous years. We did not perform any necropsies in 1994, but based on fecal analysis, prevalence of pinworms (**Syphacia citelli**) was not significantly different than in 1992 or 1993 on site 5a, and prevalence of tapeworms (**Hymenolepis citelli**) was also unchanged.*

OBJECTIVES

1. To examine the prevalence of parasites in Townsend's ground squirrels over time and with respect to squirrel sex and age.

2. To determine the effects of parasitism on over-dormancy survival in all Townsend's ground squirrels.

3. To infer whether biotic (e.g., host physiology or host population density) or abiotic factors (e.g., precipitation) are the primary factors influencing the dynamics of the parasite community in Townsend's ground squirrels.

METHODS

Methods used in 1994 for fecal collections and analysis were the same as described previously (Van Horne et al. 1992), except that we collected fecal specimens from nearly all animals captured on all 20 sites used in Study 4 instead of only 8 sites. Prevalence (number infected/number examined) of

infection in 1994 on the 8 sites sampled in 1992 and 1993 was not significantly different than prevalences on all 20 sites examined in 1994, so all sites were combined to calculate prevalences. Prevalences for the seasonal averages (Table 1) and the temporal trends (Figs. 1 and 2) were calculated following the method Wilber et al. (1994) used to calculate infections at 10-day intervals. Prevalences between years, sexes, and ages were compared using Fisher's Exact Test with a significance value of $P < 0.05$. Prevalence of infection vs. number of times captured was calculated by determining the number of times a squirrel was captured, and then calculating the ratio of the number of animals infected to the number examined for each capture category from 1 to 13 (maximum number of times a squirrel was captured). Eimerian infections were considered repeat infections if an individual was infected with the same species of eimerian on 2 dates separated by at least 15 d. Prevalence of infection for animals captured in both 1993 and 1994 was determined for 1993, and an expected prevalence was calculated based on the distribution of prevalences obtained from Fig. 3 in Wilber et al. (1993). Prevalence of infection for animals caught in 1992 and 1994 was determined for 1992, and expected prevalences were calculated based on an unpublished data set from 1992 calculated as described above for the 1994 prevalence vs. number of times captured.

Table 1. Number of squirrels infected and prevalences() (number of individuals infected divided by the number of individuals examined) of endoparasites in Townsend's ground squirrels from 1992 to 1994 at the Snake River Birds of Prey Area, near Boise, Idaho.

Species	1992	1993	1994
	N=549	N=173	N=501
Helminths			
Pterygodermatites coloradensis	6 (0.01)	0	0
Hymenolepis citelli	26 (0.05)	6 (0.03)	5 (0.04)
Syphacia citelli	26 (0.05)	3 (0.02)	5 (0.01)
Spirura infundibuliformis	3 (0.01)	2 (0.01)	0
	N=549	N=173	N=501
Eimeria			
Eimeria callospermophili	156(0.26)	80 (0.46)[a]	238(0.47)[a]
E. adaensis	162(0.27)	62 (0.36)[a]	151(0.30)
E. morainensis	62 (0.10)	28 (0.16)[a]	49 (0.10)[b]
E. pseudospermophili	20 (0.03)	14 (0.08)[a]	33 (0.07)[a]
E. bilamellata	34 (0.06)	15 (0.09)	19 (0.04)[b]
E. beecheyi	23 (0.04)	9 (0.05)	16 (0.03)
E. lateralis	12 (0.02)	2 (0.01)	16 (0.03)

[a] Values that are significantly different than 1992 ($P < 0.05$) using Fisher's Exact Test.
[b] Values that are significantly different than 1993 ($P < 0.05$) using Fisher's Exact Test.

RESULTS AND DISCUSSION

Helminth Community Dynamics

The helminth community of Townsend's ground squirrels that we observed in 1994 consisted of only 2 species (Table 1) compared to 3 species in 1993 and 4 in 1992. Neither *Spirura infundibuliformis* (listed as *Mastophora* sp. in Wilber et al. 1993) nor *Pterygodermatites coloradensis* (listed as *Pterygodermatites* sp. in Wilber et al. 1993) were observed in fecal flotations in 1994. However, ova from these 2 helminths were not observed in flotations in 1992. In 1993, only 2 flotations had *S. infundibuliformis,* and none were positive for *P. coloradensis.* These worms are probably still present on the SRBOPA, but were not detected using sucrose flotations.

Scott (1988) suggested that a decrease in the density of the host population may lead to a decrease in the prevalence of parasites due to decreased transmission rates. We did not observe a decline in the prevalence of tapeworms (*Hymenolepis citelli*) or pinworms (*Syphacia citelli*) at the sites we sampled at the SRBOPA between 1992 and 1994 even though the squirrel population decreased by >50% from 1992 to 1993 and remained low in 1994. We expected that a decrease in host population size of this magnitude would decrease the transmission rate of the helminths. In 1992, sites 4a and 4b had a large sample size and the highest prevalence of tapeworms (Van Horne et al. 1992) (Table 2). In 1993 and 1994, samples size were considerably smaller, but prevalence was not significantly affected. Tapeworm populations in Townsend's ground squirrels may be buffered from the effects of large fluctuations in the ground squirrel populations by their use of arthropod intermediate hosts and/or their potential ability to infect many of the small mammals at the SRBOPA including *Dipodomys* sp. (King and Babero 1974) and *Peromyscus maniculatus* (Frandsen and Grundmann 1959).

The prevalence of pinworms on site 5a, the only site with >1 ground squirrel infected in 1992, also was unchanged from 1992 to 1994, despite a large decrease in sample size (Table 2). However, in both 1992 and 1993 adults were more likely to be infected than juveniles (1992, 20:4; 1993, 3:0), but in 1994, all 3 infected individuals were juveniles.

If ground squirrel pinworms live <1 week in the environment like the rat pinworm (Prince 1950), transmission rates for squirrel pinworms should be sensitive to fluctuations in the density of the host populations; however, the prevalence of pinworms did not decrease with host population size. Thus, pinworms may either be longer lived in the environment than we suspected and/or behavior of the squirrels facilitates transmission even when host density is low.

The Eimerian Community

The community of eimerians in 1994 consisted of the same 7 species observed in 1992 and 1993. In 1992 and 1994, prevalence of infection was higher in adults than in juveniles for all species of eimerian except *E. pseudospermophili* in 1994, and these differences were significant for *E. callospermophili, E. adaensis* and all eimerians combined in both years. In 1993, prevalences were higher in adults in all species except *E. adaensis,* and were significant only for *E. callospermophili.* In addition, there was no significant difference between males and females in 1992 (Wilber et al. 1994) or

Table 2. Prevalence of *Hymenolepis citelli* on sites 4a and 4b, and *Syphacia citelli* on site 5a from 1992 to 1994 in Townsend's ground squirrels at the Snake River Birds of Prey Area.

Year	*Hymenolepis citelli* (prevalence)	*Syphacia citelli* (prevalence)
1992	14/236 (0.06)	20/88 (0.23)
1993	2/63 (0.03)	3/24 (0.12)
1994	2/63 (0.03)	3/17 (0.18)

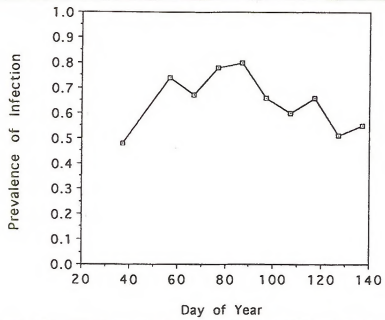

Fig. 1. Prevalence of all *Eimeria* species combined for all captures of Townsend's ground squirrels in 1994 (n = 501 individuals, 916 captures) at the Snake River Birds of Prey Area near Boise, Idaho by day of year.

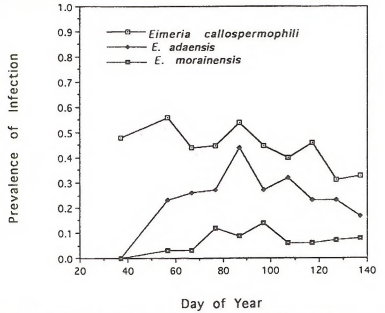

Fig. 2. Prevalence of the 3 most common *Eimeria* species in 1994 by day of year for 501 Townsend's ground squirrels captured 916 times. Data are pooled into 10-day intervals, and all duplicate records are summed, thus each data point is made up of unique individuals.

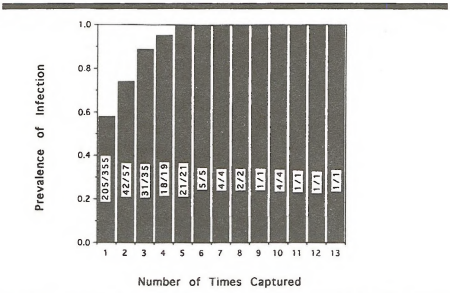

Fig. 3. The relationship between the number of times an individual Townsend's ground squirrel (*Spermophilus townsendii*) is captured and thelikelihood of observing an eimerian infection in 1994.

in 1994, but prevalence of infection in males was significantly higher than in females in 1993 (Wilber et al. 1993). Thus, in all years, *E. callospermophili* was more common in adults than in juveniles and of the 3 years, 1992 and 1994 were more similar to each other than to 1993. The differences in results for 1993 may be, in part, an aftermath of the drought which may have disrupted host-parasite interactions via change in the age structure of the host population and/or the transmission patterns of the parasites. The prevalences of only 2 species (*E. beecheyi* and *E. lateralis*) were consistent over the 3 years of the study (Table 1). The most common eimerian, *E. callospermophili*, was significantly higher in both 1993 and 1994 than in 1992, but the prevalence of the next most common species, *E. adaensis*, was significantly higher in 1993 compared to 1992, and prevalence was intermediate in 1994. *Eimeria morainensis* increased significantly in 1993, but returned to its 1992 levels this year. *Eimeria pseudospermophili* was significantly lower in 1992 than in the other 2 years while *E. bilamellata* was lowest in 1994. Reasons for inconsistencies between species are probably related to differences in host-parasite interactions and susceptibility of the parasites to abiotic conditions.

Temporal Patterns Within Years

Temporal patterns for all eimerians considered together over the entire period of squirrel activity varied between years. In 1992, prevalence of eimerians declined significantly over time, and this decline was attributed to drought (Wilber et al. 1994). In 1993, prevalences in February were similar to those in May 1992, suggesting that hosts that entered torpor with an infection, emerged from torpor infected. Prevalence then increased to about 65% and stabilized, probably because of cooler, damper weather conditions that facilitated eimerian development and longevity in the environment. In 1994, prevalence at emergence was again similar to prevalence at imergence in May 1993, but because the prevalence in May 1993 was already fairly high, and the weather in 1994 promoted eimerian survival, prevalence was more stable over time in 1994 (Fig. 1) than in previous years.

Temporal patterns for the 3 most common eimerians differed among the 3 years, but *E. morainensis* and *E. adaensis* had some striking similarities among years (Fig. 2). In 1992, *E. callospermophili* declined significantly until day 136 when prevalances began to increase (Fig. 1& 2, Wilber et al. 1994). In 1993, prevalences peaked at day 100

and declined (Fig. 2, Wilber et al. 1993), and in 1994, prevalences declined slightly, but steadily over time (Fig. 2). From 1992 to 1994, prevalences of *E. callospermophili* became more stable overall and more stable with respect to the other 2 common species. *Eimeria callospermophili* was more prevalent at every time interval only in 1994. In addition, *E. callospermophili* had prevalences >40% at first sampling period in every year. This suggests that this eimerian either survives dormancy well in the squirrels, or it is readily available in the environment when squirrels arise from hibernation, and prepatency (period of development of the parasite that occurs after the host is infected, but before the host is shedding infective propagules into the environment) is short enough that squirrels begin to shed oocysts only a few days after becoming infected. Published prepatency is 5 days (Todd and Hammond 1968; Thomas et al. 1992). *Eimeria adaensis* showed very different patterns. This eimerian started every year with prevalences <10%, peaked between day 78 and day 100, and finally declined. Our unpublished laboratory experiments show that in young of the year infected and then placed in the cold room for 7 months, this eimerian had a prepatent period of 21 days upon emergence. In fully active adults, the prepatent period is 12 to 14 days. This long prepatency may contribute to the mid-season, rather than early season, peak that is present in all years. In both 1992 and 1993, *E. adaensis* was more prevalent than *E. callospermophili* during the latter part of the squirrel period of activity. Prevalence of *E. morainensis* was relatively consistent between years.

Reinfections

Reinfections occurred in a greater percentage of the squirrels recaptured in 1994 than in previous years (Table 3), but the number of species involved declined from 1992 to 1994 (Table 3). Reinfections with *E. callospermophili* and *E. adaensis* were observed in all years, but *E. beecheyi* reinfections were observed only in 1992 and 1993. Reinfection with *E. bilamellata* was only seen in 1992. No reinfection within years was observed for the remaining 3 species. For the 56 squirrels captured in >1 year, infection with the same species in multiple years was observed for all species except *E. lateralis*. These patterns suggest that the 2 most common eimerians, which also have the highest rate of reinfection both within and between years, may be the least immunogenic, while *E. lateralis*, which was never observed to reinfect an individual, may be the most immunogenic. Preliminary analysis of the average number of oocysts observed/sample

Table 3. Prevalence of reinfections with all species of eimerian in each year from 1992 to 1994 in Townsend's ground squirrels captured more than once at intervals >15 days and between years (1992-1994) for squirrels captured in >1 year.

	1992	1993	1994	1992-1994
Total Captures	153	58	101	56
Total Reinfected	29(0.19)	19(0.33)	41(0.41)	28(0.50)
E. callospermophili	16(0.10)	15(0.26)	32(0.32)	18(0.32)
E. adaensis	11(0.07)	6 (0.10)	15(0.15)	19(0.33)
E. morainensis	0	0	0	4 (0.07)
E. pseudospermophili	0	0	0	1 (0.02)
E. bilamellata	2 (0.01)	0	0	1 (0.02)
E. beecheyi	3 (0.02)	2 (0.03)	0	3 (0.05)
E. lateralis	0	0	0	0

indicates that *E. lateralis* is more likely to occur at densities of 1000+ oocysts/coverslip examined than any other species, and Thomas et al. (1992) found that this eimerian can provoke partial immunity in *S. elegans*. Laboratory infections would be needed to corroborate our field data because the abiotic factors influencing transmission rates of the eimerians, the immunocompetence of the squirrels, and the number of times a squirrel is captured all influence the likelihood of observing a reinfection and thus may confound our results.

The decline in the number of species involved in reinfections between 1992 and 1994 suggests that the effects of the drought may have favored reinfection by some of the less common species and hindered reinfection by *E. callospermophili*. However, only the difference between 1992 and 1994 for *E. callospermophili* was significant.

Capture Frequency and Prevalence of Infection

The probability of observing an eimerian infection in a given individual increases the more often the animal is captured. In 1992 and 1993, all squirrels captured >6 times had been infected with ≥1 species of eimerian. In 1994, only 5 capture events/squirrel were required to observe infection. This decrease may be a result of the generally higher and more consistent prevalences of *E. callospermophili* and *E. adaensis* in over time in 1994 (Fig. 2) compared to other years.

Over-torpor Survival and Prevalence of Infection

Between 1992 and 1993, 49 squirrels survived the torpid period and were recaptured. These squirrels were 18% more likely to be infected with ≥1 species of eimerian in 1992, the drought year, than expected based on probability (73% observed vs. 55% expected) (Wilber et al. 1993). However, prevalence of infection in 1993 in the 20 animals captured in both 1993 and 1994 was not significantly different (80% vs. 80%); and of the 18 animals captured in 1992 and 1994, prevalence of infection in 1992 was not significantly different than expected (55% vs. 55%). We originally supposed that squirrels that survived the drought in 1992 to be recaptured in 1993 we were in better condition and thus provided better habitat for the eimerians. However, if this were the case, those animals that survived from 1992 to 1994 should also be more likely to be infected in 1992 than expected and they were not.

Effects of Host Density

Based on the data collected between 1992 and 1994, density of the Townsend's ground squirrel appears to have relatively little influence on the prevalence of eimerians; prevalence of eimerians declined in 1992 when densities were high and increased in 1993 when densities were at least 50% less than in 1992. In addition, the species assemblage was stable throughout the study. Seville (1992) found the eimerian assemblage was stable in Wyoming ground squirrels (*Spermophilus elegans*), and that the prevalence of each species was consistent over time. We found relatively large fluctuations in time, at least for the 3 most common species of eimerians in Townsend's ground squirrels. We suggest that at least some species of eimerian will persist in Townsend's ground squirrels when host densities are > 0; however, the assemblage may fluctuate from 1 to 7 eimerians in populations of Townsend's ground squirrels on sites where the squirrel population has few permanent residents and a large number of immigrants. At intermediate densities (>6 animals/ha), we suggest that all 7 species will be present at some time during the period of squirrel activity, but prevalences may be strongly influenced by dryness, host immunocompetence, and/or past history on the site. At very high host densities (>100 animals/ha), we suggest that both the assemblage and the prevalence of each eimerian species over time will be stable because only the most extreme conditions will be able to decrease the number of eimerians in the environment to negatively affect transmission rates, and hosts are readily available. Thus, host density may influence both the assemblage of eimerians observed in squirrels and the stability of that assemblage, but the relationship is non-linear. At low host densities, the assemblage itself may fluctuate, but high host densities may augment both the stability of the assemblage and the prevalence of individual eimerian species over time. At intermediate densities, although the assemblage may be stable,

Each species may fluctuate depending on which additional factors prevail during the observation period. These fluctuations may appear random and probably are difficult to predict.

This report represents preliminary findings from the 1992 to 1994 study of the parasites of Townsend's ground squirrels. Further work may result in changes and additions to the data and the methods of analysis.

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Dispersal Characteristics of Juvenile Townsend's Ground Squirrels

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ANNUAL SUMMARY

*Beginning in mid-April, we radio-collared and tracked 31 (21 male, 10 female) juvenile Townsend's ground squirrels (**Spermophilus townsendii**) on 4 sites of 2 different habitat types within the Orchard Training Area (OTA) on the Snake River Birds of Prey Area (SRBOPA). We had improved success with collar retention as compared to 1993 and were able to positively identify dispersal of 11 ground squirrels (1 female and 10 male). These dispersed an average of 447 m (range 157-1,005 m), all but 3 to a habitat type similar to their natal habitat. We did not succeed in target trapping 1993 radio-collared individuals, but 2 of 28 animals collared in 1993 were recaptured during normal Study 4 trapping activities.*

OBJECTIVES

1. To radio-collar 15 juvenile ground squirrels in each of 2 habitat types (shrub and open grassland) and determine their locations daily beginning in mid-April and ending with immergence in late June 1994.
2. To track dispersing juveniles and determine the end points of dispersal movements.
3. To follow dispersing individuals, whenever possible, and map the actual path of movement with respect to habitat and topographic features.
4. To compare sex-specific movements of radio-collared ground squirrels.
5. To determine fates (over-winter survival) of animals radio-collared in 1993 by target trapping in 1994.

METHODS

Study sites

We chose 4 BLM\IDARNG Study 4 study sites for this study that had relatively high ground squirrel

densities, were representative of different source habitat types, and had other habitat types nearby to serve as potential dispersal destinations; sites 5B and 9B (sage [*Artemisia tridentata*] sites within the OTA near the quarry north of Christmas Mountain), and Sites 10A and 10B (burned sage sites within the OTA located near the northwestern boundary). Sites 9B and 10B also had been used as radio-telemetry sites in 1993; the other sites were added to increase the potential number of juveniles and because of their proximity and similarity to these sites.

Collaring

Beginning in mid-April, we placed radio-transmitters on all eligible (defined in Olson and Van Horne 1993) juvenile ground squirrels captured on the 4 study sites. These were attached to a collar package with weights ranging from 4.46 to 5.17 g. As in 1993, we obtained radio-transmitters from Advanced Telemetry Systems, Isanti, MN. Of 54 total transmitters, 22 were newly manufactured, and 32 were refurbished (batteries and collaring material replaced) from transmitters obtained in 1993 that were either retrieved after use or not used in 1993. Six additional transmitters were returned for refurbishing but were destroyed in the process; these were not replaced with new transmitters. Juvenile ground squirrels for this study were trapped using standard Study 4 trapping procedures (Van Horne et al. 1992) both during normal Study 4 trapping efforts and with supplemental trapping.

Collaring began as soon as eligible ground squirrels were caught (11 April for Sites 10A and 10B, 1 May for Sites 5B and 9B), and continued as long as we thought uncollared juveniles that met our criteria remained. Because the guaranteed duration time of batteries powering transmitters was only 30 days, any animals still alive were re-trapped by target trapping 30 days after initial collaring and their transmitters replaced with new ones. This tactic also was used earlier (prior to 30 days) if the signal started to fail prematurely.

Tracking

Tracking procedures were identical to those used in 1993 (Olson and Van Horne 1993).

Target trapping and excavation of collars.-- To complete the objectives of the 1993 study, we attempted to determine the fates of animals that had been radio-collared in 1993 and had survived to estivation that year by target-trapping near hibernation burrows early in 1994. We also attempted to establish more exactly the fate of animals collared in 1994 by digging up collars where signals were tracked to the same location for several consecutive days. This was done immediately for locations away from Study 4 trapping grids and after trapping had concluded for locations within the grids.

RESULTS AND DISCUSSION

Collaring

We collared 31 juvenile ground squirrels with radio-transmitters in 1994: 6 males and 4 females on Site 5B; 1 male and 1 female on Site 9B; 5 males and 1 female on Site 10A; and 9 males and 4 females on Site 10B for a total of 21 males and 10 females. We were far more successful with collar retention in 1994 as compared to 1993; only 5 animals were thought to have slipped collars, and 4 of these occurred after initial transmitters were replaced or loosened to accommodate growth. We replaced 15 initial transmitters by target trapping, which was always successful. We also loosened collars on several individuals and removed 1 collar when sores were discovered.

Tracking

We recorded 1,199 attempted locations (radio checks) between 24 April and 30 June, found signals 1,147 times, and tracked animals to exact locations 613 times. On a per animal basis we averaged 38.7 checks, 37.0 finds, and 19.8 locations. We marked a mean of 11.7 unique locations per individual (363 total), with a range of 2-24. Most of these figures are substantially higher than for 1993, especially the numbers of locations marked. However, this was attributed to differences in applying hole marking criteria rather than an increase in numbers of holes used per ground squirrel. The increase in the other figures are the result of starting tracking earlier on some sites,

increased number of animals collared, and increased collar retention.

Ultimate fates of collared animals are given in Table 1. Although collar retention was much higher in 1994, there are still individuals whose fate we could not determine, despite digging up collars with stationary signals. We dug up a total of 8 collars and found 1 dead ground squirrel. The remaining collars were found intact with no squirrel. However, 5 of them were found in holes freshly dug by badgers and were in locations where no ground squirrel was likely to have been found without intervention; these animals were considered to have died of predation. The others were found in apparently undisturbed ground squirrel burrow systems, and the fate of these animals was unknown.

Our attempt to determine over-winter fates of 1993 animals by target trapping was completely unsuccessful. However, 2 animals that had been collared in 1993 were recaptured in 1994 during normal Study 4 trapping efforts; 1 of these (whose fate was not known until its recapture) had slipped a collar in 1993, the other still retained its collar, which we removed. Examination of the 4 known hibernation locations indicated that 2 were likely to have been preyed upon by badgers, 1 had fresh ground squirrel sign around it early in 1994, and the fourth did not appear to have been disturbed at all.

Altogether, 11 juveniles (10 male and 1 female) were classified as dispersers. Two of these were known to have survived to estivation, and 4 were thought to have died. Of the 6 animals that survived to estivation, 2 were known to have dispersed. Of the 12 animals that died or probably died, 6 were thought to be non-dispersers because the length of time they remained within the grid area was beyond the period when dispersal apparently took place. In summary, 91% of 11 dispersers were male; 59% of 17 males, and 14% of 7 females, which could be classified, dispersed.

The 11 dispersers travelled an average distance of 515.0 m (range: 145-1076). The 1 female known to have dispersed traveled 283 m, the second shortest distance recorded. Unlike 1993, when all dispersers ended up in the same habitat in which they were born, 3 animals in 1994 dispersed to the opposite habitat type. Two of these dispersed from sage to burn (including the only female disperser), and 1 dispersed from burn to sage; this latter individual evidently had followed a grassy strip into a large expanse of sagebrush, and halted its movements at the edge of this patch. Otherwise, dispersal patterns were similar to those found in 1993, with known litter mates dispersing in independent directions,

Table 1. Survival of all juvenile ground squirrels radio collared on the Snake River Birds of Prey Area, 1994 (sites combined, $n = 31$).

Ultimate Fate	Number of animals
Survived to estivation	6
Died (Known)	12
Unknown Fate	13
Lost signal	3
Probably estivated	1
Probably died	1
Unknown	1
Stationary signal (not dug up)	1
Unknown	1
Collar found or dug up	9
Probably slipped	4
Unknown	5

and with some animals using exploratory movements (not necessarily in the direction of eventual dispersal), and several not.

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Habitat Classification and the Ability of Habitats to Support Populations of Townsend's Ground Squirrels and Black-tailed Jackrabbits

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ANNUAL SUMMARY

In 1994, we sampled vegetation in 11 habitat types at 255 randomly located points (63 sites in the OTA, 36 sites south of the Snake River (SRV), 86 sites in the ISA excluding the OTA and south of the Snake River (NRV), and 70 sites east of the ISA (HAM)). Plant species richness was significantly lower on HAM sites than on NRV, OTA, or SRV sites. Diversity (Hill's diversity index) was similiar among areas. Total vegetative cover was significantly lower on HAM and SRV sites than on NRV and OTA sites. Total cover of exotic annuals was significantly greater on HAM and NRV sites than on OTA and SRV sites. Species richness, diversity (Hill's diversity index), total vegetative cover, and cover of exotic annuals was similar between military tracking and livestock use classes. Cover of bud sagebrush ***(Artemisia spinescens)****, shadscale* ***(Atriplex confertifolia)****, winterfat* ***(Ceratoides lanata)****, and green rabbitbrush* ***(Chrysothamnus viscidiflorus)*** *was similar among HAM, NRV, OTA, and SRV areas. Cover of big sagebrush* ***(Artemisia tridentata)*** *was significantly lower on HAM sites than on NRV or OTA sites. Density (plants/ha) was similar among areas for bud sagebrush, shadscale, and winterfat. Densities of big sagebrush and green rabbitbrush were lowest in HAM and SRV areas. Cover of cryptobiotic crusts (mosses + lichens) was similar between areas grazed in the winter and areas grazed in the spring. Cover of mosses was significantly greater on areas grazed by livestock in the spring, and cover of lichens was significantly greater on areas grazed by livestock in the winter.*

*Winter 1993-94 densities of black-tailed jackrabbits (****Lepus californicus****) along all spotlight transect routes (663.46 km) were 0.06 jackrabbits/ha (0.05-0.07, 95% C.I.). Spring 1994 densities of jackrabbits along all spotlight transect routes (659.50 km) were 0.14 jackrabbits/ha (0.12-0.16, 95% C.I.). Jackrabbit densities on historical transects were lower in winter 1993-94 and higher in spring 1994 than the previous year's values.*

Total number of Townsend's ground squirrels ***(Spermophilus townsendii)*** *captured on 42 sites within the ISA was similar between OTA and NRV sites in grassland habitats, but was significantly greater on OTA sites in shrub habitats. North UTM coordinate, cover of succulent Sandberg's bluegrass* ***(Poa secunda)****, cover of bud sagebrush, cover of tumble mustard* ***(Sisymbrium altissimum)****, and sun temperature explained 43.2% of the variation in total ground squirrel captures per site.*

INTRODUCTION

Abundant populations of Townsend's ground squirrels and black-tailed jackrabbits are needed to maintain one of the world's highest densities of nesting raptors in the Snake River Birds of Prey National Conservation Area (SRBOPNCA) (U.S. Dep. Inter. 1979, Steenhof and Kochert 1988). In recent years, public concerns were raised that intensive grazing by livestock (Yensen 1980), extensive wildfires (Kochert and Pellant 1986), and long-term military activities in the Orchard Training Area (OTA) had influenced habitat and prey communities in the SRBOPNCA. The purpose of Study 5 of the Bureau of Land Management/Idaho Army National Guard Research Project (BLM/IDARNG) is to evaluate the influence of grazing, wildfires, and military activities on vegetation, Townsend's ground squirrels, and black-tailed jackrabbits, and to provide an accurate description and spatial delineation of habitats and prey communities within the SRBOPNCA.

OBJECTIVES

1. Assess influence of military activities and livestock use on vegetation.

2. Determine the influence of military activities and livestock use on abundance of Townsend's ground squirrels and black-tailed jackrabbits.

3. Determine habitat correlates of Townsend's ground squirrel and black-tailed jackrabbit abundance.

4. Monitor trends in distribution and abundance of Townsend's ground squirrels and black-tailed jackrabbits.

5. Establish permanent transects that will be resampled at specified intervals for long-term monitoring of vegetation.

METHODS

Vegetation

An initial sample of 1,000 sites within the Integration Study Area (ISA) of the SRBOPNCA was randomly selected in 1990 (Knick 1991); number of sites was apportioned between the Orchard Training Area (OTA) and non-OTA relative to their respective areas. An additional 150 sites east of the ISA (but within the SRBOPNCA) between Mountain Home and Hammett were randomly selected in 1994. In 1994, we sampled vegetation at 255 points (63 sites in the OTA, 36 sites south of the Snake River (SRV), 86 sites in the ISA excluding the OTA and SRV (NRV), and 70 sites east of the ISA (HAM). All sites were marked in the field by a single metal fence post and their position was recorded by a Global Positioning System for future studies of long-term change (e.g., Anderson and Holte 1981, Turner 1990).

We sampled vegetation on 7, 50-m transects perpendicular to the center line of the 400-m strip transect (Fig. 1). One 50-m transect was randomly located within each 57-m segment. Therefore, each site effectively sampled a 100 x 400 m area (4 ha). We sampled vegetation (species composition, frequency, percent cover for all species) by point intercept (Floyd and Anderson 1982) from a 7-m section (252 points) at randomly determined points on each 50-m transect (Fig. 1). Scientific and common names of all plants sampled by Study 5 are listed in Appendix A.

Data from point frames were used to calculate percent cover by species, species richness, and Hill's diversity index. Species richness (*S*, number of

species present) and Hill's diversity index were determined for total species composition at a sampling site. Hill's diversity index was $H = 1/\sum p_i^2$ where p_i was the proportion of the ith species in the total sample (N_i/N) (Hill 1973, May 1981). This index equaled 1 when a single species dominated the sample; higher values resulted from increasing number of species and evenness of distribution.

When shrubs were present, shrub density, mean shrub height from ground to bottom of canopy, and mean shrub height from ground to top of canopy were determined from 20-m^2 (2.52-m radius) plots (Asherin 1973). Shrub plots were established at each end of the 7-m sections for vegetation sampling by point frame (Fig. 1).

Habitat class was estimated for a 20-m diameter circle around the center of each 7-m section for each 50-m transect, based on the classification scheme developed from all vegetation transects sampled from 1991 through 1993 (Knick et al. 1992) (Appendix B). Habitat class was also determined from percent cover values calculated from point frame data for each 50-m transect. The habitat estimate and the calculated habitat were compared. We also grouped categories for shrub (all Class 1A and 1B), grass (all Class 2A and 2B), and disturbed (all Class 1D) sites.

Military and Livestock

We determined tracking intensity by categorical estimation (presence = 1; absence = 0) of military tracks along each 100-m segment of the 5-m wide belt transect (Fig. 1). A categorical estimate (presence = 1; absence = 0) of cattle and sheep use based on presence of fecal material was also obtained along each 100-m segment of the 5-m wide belt transect (Fig. 1). Tracking and livestock scores from the 4 segments on each transect were summed and classified into low (0-2) and high (3-4) categories.

Townsend's Ground Squirrels

We live-trapped Townsend's ground squirrels from 4 April through 6 May at 56 randomly located sites within the ISA. The sampling period was designed to minimize effects of breeding movements in early spring, maximize juvenile capture, and avoid early emergence of adults.

On each site, 40 traps of 3 types (Tomahawk, Havahart, and locally fabricated) were laid out systematically in 2 parallel lines along the 400-m transect, beginning at 100 m and ending at 300 m (Fig. 1). The 2 lines of traps were spaced 20 m apart, and traps in each line were spaced 10 m apart.

Traps were placed on each site for 5 days (2 days of pre-baiting, followed by 3 days of trapping). Pieces of apple were used for bait. There were 3, 1-hour trapping sessions each day, beginning in the early morning. At first capture, squirrels were marked with hair dye to allow collection of recapture data.

The following data were collected for each trapped squirrel: 1) capture (first, recapture, mortality at first capture, dead recapture); 2) age class (juvenile, adult); 3) sex (male, female); 4) reproductive status (male [descended, not descended], female [not reproductive, pregnant, lactating]); and 5) weight. Weather data (sun temperature [thermometer placed in direct sunlight], shade temperature [thermometer placed where direct sunlight was blocked], wind speed at 10-cm height, and cloud cover) were collected during each session at each site.

Black-tailed Jackrabbits and Cattle

Black-tailed jackrabbits and cattle were counted by spotlight after sunset and before sunrise (Smith and Nydegger 1985) by driving along previously established transects (Doremus et al. 1989). Winter surveys were conducted between 30 November 1993 and 7 January 1994. Spring surveys were conducted between 4 May and 17 June 1994. Each transect was driven 2 times on separate nights.

Densities of cattle for winter 1993-94 and jackrabbits for 1994 and all previous years (1977-1993) were estimated using program DISTANCE (Laake et al. 1991), an upgraded version of the program TRANSECT (Burnham et al. 1980). The half-normal model provided the best fit for all data sets (Lebreton et al. 1991, Burnham and Anderson 1992) and was used for density estimates. Sightings of kangaroo rats (*Dipodomys ordii* and *D. microps*),

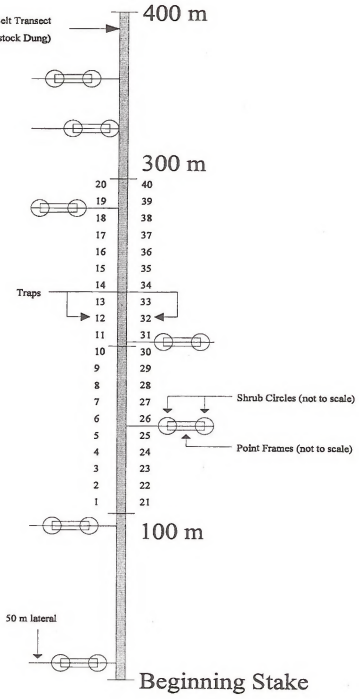

Fig. 1. Design for sampling vegetation, shrubs, military tracking, and livestock use, and Townsend's ground squirrel trapping layout at randomly located sites.

Nuttall's cottontail rabbits (*Sylvilagus nuttallii*), pygmy rabbits (*Brachylagus idahoensis*), deer mice (*Peromyscus maniculatus*), shrews (*Sorex* spp.), and voles (*Microtus* spp.) also were recorded on jackrabbit spotlight transects, but densities were not estimated.

Data Analyses

We used analysis of variance (Proc GLM, SAS Statistical Institute 1988) to test for significant differences between means for vegetation data. Site was the sample unit for all tests. Interaction terms were removed from models if they were non-significant. Significance was determined from the type III sum of squares with an alpha value of 0.05. If appropriate, pairwise comparisons among means were made using Tukey's studentized range (HSD) test with an alpha value of 0.05. Models used for each test are given in the vegetation results section.

We also used analysis of variance to test for differences in mean number of Townsend's ground squirrels captured per site between NRV and OTA sites. Site was the sample unit. Interaction terms were removed from models if they were non-significant. Significance was determined from the type III sum of squares with an alpha value of 0.05. Models used for each test are given in the Townsend's ground squirrel results section.

Linear regression (Proc REG, SAS Statistical Institute 1988) was used to determine habitat correlates of ground squirrel captures. Site was the sample unit. Habitat correlates included mean Julian date of trapping sessions, mean sun temperature, mean shade temperature, mean wind speed, cloud cover, east UTM coordinate, north UTM coordinate, and cover of cheatgrass (*Bromus tectorum*), succulent Sandberg's bluegrass, senesced Sandberg's bluegrass, bottlebrush squirreltail (*Sitanian hystrix*), bud sagebrush, big sagebrush, shadscale, Nuttall saltbush (*Atriplex nutallii*), winterfat, green rabbitbrush, spiny hopsage (*Grayia spinosa*), Russian thistle (*Salsola iberica*), and tumble mustard. An alpha value of 0.15 was used with the stepwise procedure to choose the best model.

A Z-test was used to test for significant differences between area means of jackrabbit densities, with an alpha value of 0.05.

RESULTS

Vegetation

Of the 32 habitat types in Appendix B, we found 11 on 255 randomly selected sites sampled in 1994 (Table 1). Agreement was poor between field habitat estimates and habitats determined from point frame data (29.9%). Agreement improved when habitats were grouped into shrub, disturbed, and grassland categories (56.4%). Most errors (77.2%) were grasslands that were estimated in the field to be disturbed habitats.

Table 1. Frequency of habitats by area (calculated from point frame data) found on 255 randomly located sites sampled in 1994.

	Habitats										
Area	1A1	1B1	1B2	1B3	1B7	1B0	1Ba	1D3	2A1	2A2	2B2
HAM		7					1	2		52	8
NRV	6	19	3	4	2	1		3	5	34	9
OTA	1	20	1	1					8	31	1
SRV	1	9				1			3	21	1

Plant species richness ranged from 2 to 13 on 255 randomly located sites; Hill's diversity index ranged from 1.1 to 6.5; total cover of vegetation ranged from 1.0% to 62.3%; and total cover of exotic annuals ranged from 0.0% to 44.6%. The full model to test the effect of area and habitat on richness, Hill's diversity index, total vegetation cover, and total exotic annual cover included the area and habitat terms and the area*habitat interaction term. The area*habitat interaction was not significant for richness ($P = 0.6896$), Hill's diversity index ($P = 0.6711$), total vegetation cover ($P = 0.5291$), and total exotic annual cover ($P = 0.5633$). Therefore, the interaction term was dropped from the model and pairwise comparisons among areas and among habitats were made using Tukey's studentized range (HSD) test.

HAM sites had significantly lower ($P < 0.05$) species richness than NRV, OTA, and SRV sites (Table 2). There was no significant difference ($P > 0.05$) in Hill's diversity index among areas. Total plant ground cover was significantly greater ($P < 0.05$) on NRV and OTA sites than on HAM and SRV sites. Total ground cover of exotic annuals was significantly lower ($P < 0.05$) on OTA and SRV sites than on NRV and HAM sites.

Disturbed habitats had significantly lower ($P < 0.05$) species richness and Hill's diversity index than shrub sites (Table 3). Species richness and Hill's diversity index in grassland habitats was not significantly different ($P > 0.05$) from that in disturbed or shrub habitats. There was no significant difference ($P > 0.05$) in total plant ground cover among habitats. There was significantly greater ($P < 0.05$) ground cover of exotic annuals in disturbed habitats.

We encountered 16 shrub species (low sagebrush [*Artemisia arbuscula*], bud sagebrush, big sagebrush, fourwing saltbush [*Atriplex canescens*], shadscale, Nuttall saltbush, winterfat, rubber rabbitbrush [*Chrysothamnus nauseosus*], green rabbitbrush, spiny hopsage, forage kochia [*Kochia*

Table 2. Species richness, Hill's diversity index, total cover, and exotic cover by area for 255 randomly located sites sampled in 1994.

Variable	N Obs	Area	Min	Max	Mean	S.E.	Tukey*
Richness	70	HAM	2	11	5.86	0.23	B
	86	NRV	2	13	6.80	0.24	A
	63	OTA	3	11	6.98	0.24	A
	36	SRV	2	13	6.33	0.40	A
Diversity	70	HAM	1.14	4.35	2.71	0.11	A
	86	NRV	1.10	5.31	2.58	0.10	A
	63	OTA	1.33	6.48	2.66	0.10	A
	36	SRV	1.17	6.47	2.82	0.21	A
Total cover	70	HAM	5.56	47.73	24.84	1.05	B
	86	NRV	4.25	62.25	33.46	1.45	A
	63	OTA	1.02	58.39	31.25	1.33	A
	36	SRV	1.98	45.24	21.90	1.61	B
Exotic cover	70	HAM	1.25	44.56	16.92	1.24	A
	86	NRV	0.00	41.16	15.96	1.21	A
	63	OTA	0.00	40.48	9.21	0.95	B
	36	SRV	0.00	31.52	8.12	1.35	B

*Tukey's studentized range (HSD) test. Area means with the same letter within a variable are not significantly different.

Table 3. Species richness, Hill's diversity index, total cover, and exotic cover by habitat for 255 randomly located sites sampled in 1994.

Variable	N Obs	Hab[a]	Min	Max	Mean	S.E.	Tukey[b]
Richness	5	DST[c]	2	10	4.60	1.40	B
	173	GRS[d]	2	13	6.32	0.17	AB
	77	SHB[e]	2	11	7.09	0.21	A
Diversity	5	DST	1.10	2.55	2.04	0.25	B
	173	GRS	1.14	6.48	2.57	0.07	AB
	77	SHB	1.41	6.47	2.95	0.10	A
Total cover	5	DST	22.73	36.34	30.28	2.24	A
	173	GRS	1.02	58.39	26.85	0.86	A
	77	SHB	10.54	62.25	33.47	1.40	A
Exotic cover	5	DST	21.09	31.97	26.08	1.92	A
	173	GRS	0.00	44.56	15.54	0.75	B
	77	SHB	0.00	41.16	7.93	1.06	B

[a]Habitat
[b]Tukey's studentized range (HSD) test. Habitat means with the same letter within a variable are not significantly different.
[c]Disturbed
[d]Grassland
[e]Shrubland

prostrata] [introduced from Eurasia], bitterbrush [*Purshia tridentata*], purple sage [*Salvia dorrii*], greasewood [*Sarcobatus vermiculatus*], gray horsebrush [*Tetradymia canescens*], and littleleaf horsebrush [*Tetradymia glabrata*]) in the shrub circles on 255 randomly located sites sampled in 1994. All species found in the shrub circles except gray horsebrush also were encountered in the point frames.

The full model to test the effect of area on shrub cover (point frame data), and shrub density, shrub height from ground to top of canopy, and shrub height from ground to bottom of canopy (shrub circle data) included the area and species terms and the area*species interaction term. The area*species interaction was significant ($P = 0.0001$) for shrub cover, density and ground to top of canopy height, but was not significant for ground to bottom of canopy height ($P = 0.2259$). Therefore, pairwise comparisons among areas were made for each of the five most important shrub species (bud sagebrush, big sagebrush, shadscale, winterfat, green rabbitbrush) using Tukey's studentized range (HSD) test for shrub cover, shrub density, shrub height from ground to bottom of canopy , and shrub height from ground to top of canopy.

Ground cover of big sagebrush was significantly greater ($P < 0.05$) on NRV and OTA sites than on HAM sites (Table 4). Big sagebrush ground cover on SRV sites was not significantly different ($P > 0.05$) than on HAM, NRV, or OTA sites. Percent ground cover did not differ ($P > 0.05$) among areas for bud sagebrush, shadscale, winterfat and green rabbitbrush.

Density of big sagebrush was significantly greater ($P < 0.05$) on OTA sites than on HAM or SRV sites (Table 5). Density of big sagebrush on NRV sites did not differ significantly ($P > 0.05$) from that on HAM, OTA, or SRV sites. Green rabbitbrush density was significantly greater ($P < 0.05$) on OTA sites than on SRV sites. There was no significant difference ($P > 0.05$) between green rabbitbrush density on HAM or NRV sites and that on OTA or

Table 4. Percent cover of 5 major shrub species by area for 255 randomly located sites sampled in 1994.

Species	N Obs	Area	Min	Max	Mean	S.E.	Tukey[a]
arsp[b]	70	HAM	0	0.00	0.00		A
	86	NRV	0	6.12	0.26	0.10	A
	63	OTA	0	4.48	0.14	0.09	A
	36	SRV	0	1.87	0.09	0.06	A
artr[c]	70	HAM	0	23.92	1.35	0.49	B
	86	NRV	0	30.67	5.01	0.89	A
	63	OTA	0	25.74	5.51	0.96	A
	36	SRV	0	31.63	3.87	1.13	AB
atco[d]	70	HAM	0	0.57	0.01	0.01	A
	86	NRV	0	7.60	0.56	0.17	A
	63	OTA	0	18.25	0.39	0.30	A
	36	SRV	0	3.97	0.36	0.16	A
cela[e]	70	HAM	0	0.00	0.00		A
	86	NRV	0	12.59	0.63	0.24	A
	63	OTA	0	8.11	0.22	0.14	A
	36	SRV	0	2.38	0.08	0.07	A
chvi[f]	70	HAM	0	3.12	0.18	0.07	A
	86	NRV	0	8.56	0.31	0.14	A
	63	OTA	0	8.11	0.37	0.16	A
	36	SRV	0	0.45	0.02	0.01	A

[a]Tukey's studentized range (HSD) test. Area means with the same letter within a variable are not significantly different.
[b]*Artemisia spinescens*
[c]*Artemisia tridentata*
[d]*Atriplex confertifolia*
[e]*Ceratoides lanata*
[f]*Chrysothamnus viscidiflorus*

SRV sites. Density of bud sagebrush, shadscale, and winterfat did not differ significantly ($P > 0.05$) among areas.

Height from ground to canopy bottom of big sagebrush was significantly lower ($P < 0.05$) on OTA sites than on HAM, NRV, or SRV sites (Table 6). Height from ground to canopy bottom of shadscale was significantly greater ($P < 0.05$) on SRV sites than on HAM sites. There was no significant difference ($P > 0.05$) in height from ground to canopy bottom of shadscale on NRV or OTA sites and that on HAM or SRV sites. Bud sagebrush, winterfat, and green rabbitbrush height from ground to canopy bottom was not significantly different ($P > 0.05$) among areas.

Big sagebrush height from ground to canopy top on SRV sites was significantly greater ($P < 0.05$) than that on HAM, NRV or OTA sites (Table 7). Height from ground to canopy top of big sagebrush on HAM or NRV sites was significantly greater ($P <$

Table 5. Density (plants/ha) of 5 major shrub species by area for 255 randomly located sites sampled in 1994.

Species	N Obs	Area	Min	Max	Mean	S.E.	Tukey[a]
arsp[b]	70	HAM	0	393	6	6	A
	86	NRV	0	9643	659	211	A
	63	OTA	0	38286	924	621	A
	36	SRV	0	3429	265	113	A
artr[c]	70	HAM	0	9857	1058	290	B
	86	NRV	0	78714	5432	1269	AB
	63	OTA	0	43643	8854	1451	A
	36	SRV	0	18571	2128	734	B
atco[d]	70	HAM	0	464	9	7	A
	86	NRV	0	19107	740	269	A
	63	OTA	0	10571	295	190	A
	36	SRV	0	1893	247	93	A
cela[e]	70	HAM	0	36	1	1	A
	86	NRV	0	19036	877	358	A
	63	OTA	0	16714	463	284	A
	36	SRV	0	1143	41	32	A
chvi[f]	70	HAM	0	1964	151	46	AB
	86	NRV	0	19929	559	269	AB
	63	OTA	0	20250	1236	469	A
	36	SRV	0	1500	45	42	B

[a]Tukey's studentized range (HSD) test. Area means with the same letter within a variable are not significantly different.
[b]*Artemisia spinescens*
[c]*Artemisia tridentata*
[d]*Atriplex confertifolia*
[e]*Ceratoides lanata*
[f]*Chrysothamnus viscidiflorus*

0.05) than that on OTA sites. Height from ground to canopy top of shadscale was significantly greater ($P < 0.05$) on SRV sites than on HAM sites. There was no significant difference ($P > 0.05$) between height from ground to canopy top of shadscale on NRV or OTA sites and that on HAM or SRV sites. Height of green rabbitbrush from ground to top of canopy was significantly greater ($P < 0.05$) on SRV sites than on HAM, NRV, or OTA sites. There was no significant difference ($P > 0.05$) among areas in height from ground to canopy top for bud sagebrush or winterfat.

Military Use and Grazing

The full model to test the effect of military tracking category (low vs. high) on total vegetation cover, total cover of exotic annuals, species richness and Hill's diversity index included the military tracking category and habitat terms, and the military tracking category*habitat interaction term. Only data from the 63 OTA sites were used to test the effect of the military tracking category. The interaction term was non-significant for total vegetation cover ($P = 0.8598$), exotic annual cover ($P = 0.8622$), species

Table 6. Height from ground to canopy bottom for 5 major shrub species by area for 255 randomly located sites sampled in 1994.

Species	N Obs	Area	Min	Max	Mean	S.E.	Tukey[a]
arsp[b]	1	HAM	2	7	4.18		A
	15	NRV	0	16	1.76	0.45	A
	10	OTA	0	11	1.83	0.73	A
	12	SRV	0	10	2.12	0.70	A
artr[c]	28	HAM	0	71	7.08	1.08	A
	42	NRV	0	90	7.52	1.03	A
	41	OTA	0	51	3.43	0.61	B
	22	SRV	0	54	8.08	1.10	A
atco[d]	2	HAM	0	10	1.47	0.07	B
	14	NRV	0	37	3.95	0.56	AB
	3	OTA	0	33	4.18	0.67	AB
	7	SRV	0	30	5.85	1.02	A
cela[e]	1	HAM	6	6	6.00		A
	13	NRV	0	18	3.99	0.54	A
	6	OTA	0	14	3.49	0.35	A
	5	SRV	0	13	4.29	0.67	A
chvi[f]	21	HAM	0	35	6.89	0.78	A
	12	NRV	0	47	4.54	0.82	A
	11	OTA	0	34	3.26	1.44	A
	4	SRV	0	19	3.88	1.09	A

[a]Tukey's studentized range (HSD) test. Area means with the same letter within a variable are not significantly different.
[b]*Artemisia spinescens*
[c]*Artemisia tridentata*
[d]*Atriplex confertifolia*
[e]*Ceratoides lanata*
[f]*Chrysothamnus viscidiflorus*

richness ($P = 0.0815$), and Hill's diversity index ($P = 0.5804$), so we used the reduced model to detect differences between means for all variables. There was no significant difference between low and high military tracking categories in total vegetation cover ($P = 0.4214$), total cover of exotic annuals ($P = 0.8435$), species richness ($P = 0.7325$), or Hill's diversity index ($P = 0.5127$) (Table 8). There was not enough data from point frames to conduct tests based on percent cover of tracking.

Density of cattle was estimated to be 0.016 cattle/ha, and mean number of cattle in a group was 5.8 on the winter 1993-94 jackrabbit spotlight transects in the ISA, south of the drift fence, and north of the Snake River. No cattle were encountered in the OTA during the observation periods. Cattle density was not estimated for the spring 1994 jackrabbit spotlight transects because most cattle had already been removed from the range by this time.

Table 7. Height from ground to canopy top for 5 major shrub species by area for 255 randomly located sites sampled in 1994.

Species	N Obs	Area	Min	Max	Mean	S.E.	Tukey[a]
arsp[b]	1	HAM	10	26	19.27		A
	15	NRV	1	53	10.66	1.30	A
	10	OTA	1	50	11.43	4.37	A
	12	SRV	2	40	11.65	2.29	A
artr[c]	28	HAM	3	125	34.51	3.02	B
	42	NRV	1	187	32.53	3.10	B
	41	OTA	1	132	19.45	1.57	C
	22	SRV	1	167	46.62	5.16	A
atco[d]	2	HAM	2	25	10.13	2.67	B
	14	NRV	2	72	19.66	1.48	AB
	3	OTA	2	68	21.34	3.11	AB
	7	SRV	3	85	25.43	3.10	A
cela[e]	1	HAM	29	29	29.00		A
	13	NRV	1	80	24.60	2.33	A
	6	OTA	5	66	22.96	3.43	A
	5	SRV	8	53	24.64	3.34	A
chvi[f]	21	HAM	3	101	31.14	2.92	B
	12	NRV	2	113	26.70	3.45	B
	11	OTA	2	84	15.50	3.29	B
	4	SRV	5	74	56.02	13.29	A

[a]Tukey's studentized range (HSD) test. Area means with the same letter within a variable are not significantly different.
[b]*Artemisia spinescens*
[c]*Artemisia tridentata*
[d]*Atriplex confertifolia*
[e]*Ceratoides lanata* .
[f]*Chrysothamnus viscidiflorus*

Table 8. Species richness, Hill's diversity index, total cover, and exotic cover by military tracking classs for 63 randomly located OTA sites sampled in 1994.

Variable	N Obs	Military[a]	Minimum	Maximum	Mean	Std Error
Richness	25	LOW[b]	3	11	6.88	0.42
	38	HIGH[c]	4	11	7.05	0.30
Diversity	25	LOW	1.46	6.48	2.74	0.19
	38	HIGH	1.33	4.21	2.61	0.11
Total cover	25	LOW	1.02	58.39	29.92	2.41
	38	HIGH	8.79	51.25	32.13	1.56
Exotic cover	25	LOW	0.00	40.48	9.44	1.65
	38	HIGH	0.00	24.77	9.05	1.16

[a]Military tracking category.
[b]Tank tracks found in ≤2 100-m sections of the 400-m belt transect.
[c]Tank tracks found in >2 100-m sections of the 400-m belt transect.

The full model to test the effect of livestock use category (low vs. high) on total vegetation cover, total cover of exotic annuals, species richness, and Hill's diversity index included the livestock use category, area, and habitat terms, and the livestock use category*area and livestock use category*habitat interaction terms. Neither interaction term was significant for total vegetation cover (P = 0.2567, 0.1575), exotic annual cover (P = 0.1953, 0.1220), species richness (P = 0.5464, 0.3483), or Hill's diversity index (P = 0.0786, 0.4049), so the reduced model was used to detect differences between livestock use categories for all variables. There was no significant difference in total percent cover (P = 0.7852), total percent cover of exotic annuals, (P = 0.8152) species richness (P = 0.8028), and Hill's diversity index (P = 0.8151) between low and high livestock use categories (Table 9). There was not enough data from point frames to conduct tests based on percent cover of livestock dung.

The full model to test the effect of livestock grazing season (winter vs. spring) on ground cover of lichens, mosses, and lichens + mosses (crust) included the grazing season, area, and habitat terms, and the grazing season*area and grazing season*habitat interaction terms. Only the 176 sites north (spring grazing) and south (winter grazing) of the drift fence were used in the analyses. The grazing season*area interaction term was not significant for ground cover of lichen (P = 0.6686), moss (P = 0.3477), or crust (P = 0.5744) so area and its interaction were removed from the model. The grazing season*habitat interaction was not significant for cover of moss (P = 0.6742) or crust (P = 0.1907), but was significant for percent cover of lichen (P = 0.0138). Therefore the reduced model was used to test the effect of season of grazing on ground cover for all habitats for moss and crust, and by habitat for lichen.

Cover of moss with spring grazing was significantly greater (P = 0.0475) than that for winter grazing (Table10). Cover of lichen in grassland habitats was significantly greater (P = 0.0079) for winter vs. spring grazing. Cover of lichen in shrub habitats was also significantly greater (P = 0.0001) for winter grazing. There was no significant difference (P = 0.7202) in crust cover between winter and spring grazing. There were insufficient data to test the influence of season of grazing on cover of lichen in disturbed habitats.

Table 9. Species richness, Hill's diversity index, total cover, and exotic cover by livestock use class for 255 randomly located sites sampled in 1994.

Variable	N Obs	Livestock[a]	Minimum	Maximum	Mean	Std Error
Richness	40	LOW[b]	2	13	6.60	0.34
	215	HIGH[c]	2	13	6.51	0.15
Diversity	40	LOW	1.18	5.83	2.64	0.18
	215	HIGH	1.10	6.48	2.68	0.06
Total cover	40	LOW	1.98	57.77	29.39	2.55
	215	HIGH	1.02	62.25	28.83	0.75
Exotic cover	40	LOW	0.00	41.16	13.10	1.90
	215	HIGH	0.00	44.56	13.52	0.69

[a]Livestock use category.
[b]Cow or sheep dung found in ≤2 100-m sections of the 400-m belt transect.
[c]Cow or sheep dung found in >2 100-m sections of the 400-m belt transect.

Table 10. Percent cover of lichen, moss, and crust (lichen+moss) by season of livestock grazing and habitat class for 176 randomly located sites sampled in 1994.

Variable	N Obs	Habitat	Season[a]	Min	Max	Mean	S.E.
Lichen	2	DISTURBED	SPRING	0.00	0.00	0.00	
	1		WINTER	0.34	0.34	0.34	
	58	GRASSLAND	SPRING	0.00	5.56	0.83	0.12
	48		WINTER	0.00	9.07	1.65	0.30
	38	SHRUB	SPRING	0.00	4.54	1.74	0.20
	29		WINTER	0.17	10.94	4.18	0.52
Moss	98	ALL	SPRING	0.00	15.65	4.54	0.37
	78	ALL	WINTER	0.00	16.38	3.40	0.44
Crust	98	ALL	SPRING	0.00	19.56	5.70	0.45
	78	ALL	WINTER	0.00	27.32	5.97	0.63

[a]Season of grazing by livestock (spring, north of drift fence; winter, south of drift fence).

Black-tailed Jackrabbits

Winter 1993-94 densities of black-tailed jackrabbits along all spotlight transect routes (663.46 km) were 0.06 jackrabbits/ha (0.05-0.07, 95% C.I.). Spring 1994 densities of jackrabbits along all spotlight transect routes (659.50 km) were 0.14 jackrabbits/ha (0.12-0.16, 95% C.I.). Jackrabbit densities on historical transects were lower in winter 1993-94 and higher in spring 1994 than the previous year's values (Fig. 2).

Jackrabbit densities in winter surveys on historical transects did not differ significantly from transects established by Study 5 (Table 11). There was no significant difference in jackrabbit densities in winter surveys between NRV and OTA transects (Table 11). Winter surveys showed no significant difference in jackrabbit densities between transects north vs. south of the drift fence (Table 11). Jackrabbit densities on winter surveys were, however, significantly greater on transects south of the Snake River than north of the river (Table 11).

Sightings of jackrabbits in spring surveys were significantly greater on historical transects than on transects established by Study 5 (Table 12). Spring jackrabbit densities were significantly higher on transects inside the OTA than those outside the OTA (Table 12). Spring density estimates were higher north of the Snake River than south of the river (Table 12) . Jackrabbit densities were higher on transects north of the grazing drift fence than south of the fence during spring surveys (Table 12).

We also observed 1 Nuttall's cottontail rabbit, 198 kangaroo rats, and 1 deer mouse on winter spotlight transects. On spring transects, we counted 3 Nuttall's cottontail rabbits, 1 pygmy rabbit, 858 kangaroo rats, 1 shrew, and 21 deer mice.

Townsend's Ground Squirrels

We captured 412 Townsend's ground squirrels (189 males, 215 females, 8 undetermined sex) in 468 trapping sessions on 56 randomly located sites in the ISA during spring 1994. Adults comprised 54% of the males captured and 61% of the females. Only 42 of the sites were trapped for 3 days and 3 sessions per day.

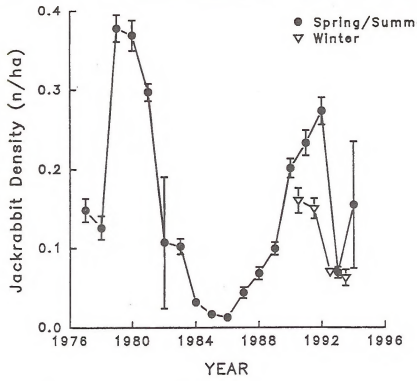

Fig. 2. Densities of blacktailed jackrabbits (± coefficient of variation) on spring and winter historical transects in the Snake River Birds of Prey National Conservation Area from 1977 through 1994.

Table 11. Pairwise comparisons of jackrabbit density estimates for winter 1993-1994 surveys.

Transect	Km	N	Density	95% C.I.	*Z*	*P*
Historical	464.93	129	0.063	0.052-0.763	1.64	n.s.
Study 5 New	198.52	46	0.046	0.033-0.065		
NRV	396.44	94	0.054	0.043-0.067	0.88	n.s
OTA	116.26	34	0.044	0.030-0.065		
N. Drift Fence	141.43	39	0.068	0.046-0.099	1.36	n.s.
S. Drift Fence	371.26	89	0.048	0.037-0.061		
N. Snake River	536.70	129	0.051	0.042-0.062	2.67	0.01
S. Snake River	126.76	46	0.108	0.074-0.156		

Table 12. Pairwise comparisons of jackrabbit density estimates for spring 1994 surveys.

Transect	Km	N	Density	95% C.I.	Z	P
Historical	460.98	295	0.155	0.132-0.181	4.15	0.001
Study 5 New	198.52	77	0.084	0.065-0.110		
NRV	390.29	165	0.102	0.083-0.124	6.45	0.001
OTA	118.45	179	0.358	0.290-0.441		
N. Drift Fence	137.47	124	0.409	0.325-0.515	5.74	0.001
S. Drift Fence	371.26	220	0.123	0.101-0.150		
N. Snake River	532.74	344	0.159	0.138-0.184	7.76	0.001
S. Snake River	126.76	28	0.043	0.028-0.065		

We used the 42 sites with 9 complete trapping sessions in the data analyses. The full model used to test the effect of area (NRV vs. OTA) on captures included the area and habitat terms, and the area*habitat interaction term. The interaction term was significant ($P = 0.0095$). Therefore we used the reduced model to test the effect of area by habitat.

There was no significant difference ($P = 0.4934$) between areas in grassland habitats (Table 13). Captures in shrub habitats were significantly greater ($P = 0.0023$) on OTA sites than on NRV sites.

The regression model produced from the stepwise regression procedure for total captures per site ($r^2 = 0.4320$) included the north UTM coordinate, sun temperature (°C), succulent Sandberg's bluegrass cover, bud sagebrush cover, and tumble mustard cover (Table 14). The north UTM coordinate provided half of the explanatory power of the model, followed by bud sagebrush cover, sun temperature, green Sandberg's bluegrass cover, and tumble mustard cover (Table 15).

DISCUSSION

Results are discussed in the context of the principal research questions of the BLM/IDARNG Research Project.

Table 13. Mean number of captures per site by area and habitat for 42 sites randomly established in the NRV and OTA during spring 1994.

Habitat	Area	N	Minimum	Maximum	Mean	Std Error
Disturbed	NRV	1	0	0	0.00	
Grassland	NRV	16	0	26	6.00	2.24
	OTA	12	0	21	8.25	2.25
Shrub	NRV	9	0	9	1.89	0.95
	OTA	4	1	34	20.25	7.03

Table 14. Regression model for total Townsend's ground squirrel captures on 42 sites randomly established in the ISA during spring 1994.

Variable	Estimate	S.E.	Type II S.S.	*F*	*P*
Intercept	-1615.53	498.574	587.88	10.50	0.0026
North UTM	0.00034	0.00010	584.47	10.44	0.0026
Succulent *Poa secunda*[a]	0.37467	0.17648	252.37	4.51	0.0407
Artemisia spinescens[b]	4.17058	1.62008	371.05	6.63	0.0143
Sisymbrium altissimum[c]	-4.93014	2.47619	221.96	3.96	0.0541
Sun Temperature	0.48413	0.21735	277.79	4.96	0.0323

[a]Sandberg's bluegrass
[b]Bud sagebrush
[c]Tumble mustard

Table 15. Correlation coefficients of the regression model for total Townsend's ground squirrel captures on 42 sites randomly established in the ISA during spring 1994.

Variable	Partial r^2	Model r^2	*C(p)*
North UTM	0.2049	0.2049	-1.1113
Artemisia spinescens[a]	0.0673	0.2722	-2.2333
Sun temperature	0.0487	0.3209	-2.4915
Succulent *Poa secunda*[b]	0.0486	0.3695	-2.7466
Sisymbrium altissimum	0.0625	0.432	-3.6483

[a]Bud sagebrush
[b]Sandberg's bluegrass
[c]Tumble mustard

What soil and vegetation characteristics are associated with abundance of Townsend's ground squirrels and black-tailed jackrabbits?

No attempt was made to correlate soil characteristics with Townsend's ground squirrel and black-tailed jackrabbit populations in 1994 because no soil data were collected. We will analyze soil data collected previously (Knick 1993) for the final report.

Small scale livetrapping of Townsend's ground squirrels was instituted in spring 1994 to correlate ground squirrel abundance with vegetation. Linear regression showed a positive correlation between total number of ground squirrel captures per site and cover of bud sagebrush and succulent Sandberg's bluegrass, and a negative correlation with cover of tumble mustard. Vegetation, however, only accounted for 17.8% of the variation in total ground squirrel captures per site. Geographic (north UTM coordinate) and environmental (sun temperature) variables accounted for 20.5% and 4.9% of the

variation in total ground squirrel captures, respectively. Over half of the variation in ground squirrel abundance is currently unexplained, and may be related to distance from source populations for colonization, soil characteristics, fires, or stochastic effects. We used total captures rather than total individuals captured based on the assumption that there was equal opportunity for captures and recaptures on all sites. Further work will be undertaken in conjunction with Study 4 to test this assumption and to attempt to correlate ground squirrel abundance with vegetative characteristics for the final report.

Jackrabbits have been censused in the Snake River Birds of Prey Area by night spotlight counts using line transect methods since 1977 (Wolfe et al. 1977). Black-tailed jackrabbits are cyclic with approximate 7-12 year intervals between peaks (Johnson and Peek 1984). In the Snake River Birds of Prey National Conservation Area, densities peaked in 1979 and again in 1990-92. Estimates of jackrabbit densities decreased in winter 1993-94 from 1991-92 and 1992-93 winter levels. Densities increased, however, from spring 1993 to spring 1994. Thus, it appears that jackrabbit densities are near the bottom of this cycle.

We are currently developing a habitat map of habitat-use potential (Clark et al. 1993) for black-tailed jackrabbits from the sighting locations on rabbit surveys and multiple GIS layers. Habitat variables, such as diversity, habitat type, distance to watering tanks, or any contoured variable, will be used to develop a mean vector of ideal habitat characteristics from sight locations. The vector of habitat characteristics associated with each cell in the GIS map can then be used to generate the Mahalanobis distance statistic, a measure of dissimilarity from the ideal habitat vector. A map of probability of each cell being a ideal habitat cell can be produced by recoding the Mahalanobis distance statistic into an associated Chi-square probability (Clark et al. 1993). The resulting map would provide a spatial representation of areas consisting of jackrabbit habitats. A similar map may be developed for ground squirrel habitats.

Have changes in vegetation resulting from wildfires affected the abundance of Townsend's ground squirrels and black-tailed jackrabbits?

This question will be answered when ground squirrel and jackrabbit abundance data are analyzed with respect to burn map data.

Do military training activities affect abundance of Townsend's ground squirrels and black-tailed jackrabbits on either a short- or long-term basis?

Total numbers of ground squirrels captured per site were similar in grassland habitats inside and outside the OTA. The relatively small sample size in conjunction with inherent spatial variability may be responsible for the much greater number of captures inside the OTA than outside the OTA in shrub habitats.

Winter 1993-94 jackrabbit densities were similar inside the OTA and in the NRV, but spring 1994 densities were significantly greater inside the OTA than in the NRV. The differences in these estimates may represent differential population dynamics or seasonal movements. Seasonal movements of jackrabbits have been documented in southeastern Idaho (Grant 1987) and northern Utah (Smith 1990).

Significantly greater height from ground to bottom and top of canopy of big sagebrush in the NRV than in the OTA likely reflects a greater proportion of seedlings on OTA sites. Thus, there may be improved hiding cover outside the OTA for small mammals in big sagebrush habitat because of the taller plants and more opportunity to get under plant cover.

Do prey densities or vegetation and soil characteristics favored by prey vary with livestock use?

Category of livestock use determined by presence of fecal material did not significantly affect species richness, Hill's diversity index, total vegetative cover, or cover of exotic annuals.

Cryptobiotic crusts may be important to soil stabilization and nutrient cycling and thus, to total ecosystem function. The significantly greater moss cover on areas grazed in the spring than on areas grazed in the winter and the significantly greater lichen cover on areas grazed in the winter than on areas grazed in the spring should be interpreted with caution. These results may reflect geographic differences (areas north of the drift fence are grazed in the spring, areas south of the drift fence are grazed in the winter) more than differences in season of grazing.

Jackrabbit densities north of the grazing drift fence were significantly greater in spring 1994 than those south of the drift fence. Thus, areas with spring grazing had higher jackrabbit densities than those with winter grazing. This may be a result of higher forage availability for jackrabbits on the spring grazing areas during winter, when forage availability may be most limiting. Alternatively, the difference may be related to geographic location or other factors (e.g., fire history) rather than season of grazing.

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Appendix A.	Acronym, scientific, and common names of plant species identified at random sampling sites by Study 5 of the BLM/IDARNG Research Project, 1991 through 1994 (* Indicates species encountered in 1994).
Acronym	Scientific Name	Common Name
agcr	*Agropyron cristatum*	Fairway crested wheatgrass
agde*	*Agropyron desertorum*	Standard crested wheatgrass
agdi	*Agrostis stolonifera*	Redtop bentgrass
agel	*Agropyron elongatum*	Tall wheatgrass
agri	*Agropyron riparium*	Streambank wheatgrass
agsm*	*Agropyron smithii*	Western wheatgrass
agsp*	*Agropyron spicatum*	Bluebunch wheatgrass
agtr*	*Agropyron triticeum*	Annual wheatgrass
alac*	*Allium acuminatum*	Tapertip onion
alce*	*Allium cernuum*	Cultivated onion
alne*	*Allium nevadense*	Wild onion
amal	*Amaranthus albus*	Pigweed amaranth
amca	*Amaranthus californicus*	California amaranth
amre*	*Amaranthus retroflexus*	Redroot amaranth
amte*	*Amsinckia tessellata*	Western fiddleneck
andi*	*Antennaria dimorpha*	Low pussytoes
arar*	*Artemisia arbuscula*	Low sagebrush
arfr*	*Arenaria franklinii*	Sandwort
arca	*Artemisia cana*	Silver sagebrush
arsp*	*Artemisia spinescens*	Bud sagebrush
artr*	*Artemisia tridentata*	Big sagebrush
assp*	*Astragalus* spp.	Milkvetch
atca*	*Atriplex canescens*	Fourwing saltbush
atco*	*Atriplex confertifolia*	Shadscale
atnu*	*Atriplex nuttallii*	Nuttall saltbush
baho*	*Balsamorhiza hookeri*	Hooker balsamroot
basa*	*Balsamorhiza sagittata*	Arrowleaf balsamroot
brru	*Bromus rubens*	Foxtail brome
brte*	*Bromus tectorum*	Cheatgrass brome
cabr4	*Calochortus bruneaunis*	Bruneau mariposa lily
capi*	*Caulanthus pilosus*	Wild cabbage
cela*	*Ceratoides lanata*	Winterfat
chal*	*Chenopodium album*	Lamb's quarters
chdo*	*Chaenactia douglassii*	Dusty Maiden
chfr	*Chenopodium fremontii*	Fremont goosefoot
chle	*Chysanthemum leucanthemum*	Oxeye chrysanthemum
chna*	*Chrysothamnus nauseosus*	Rubber rabbitbrush

Appendix A. Continued

Acronym	Scientific Name	Common Name
chte	*Chorispora tenella*	Common bluemustard
chvi	*Chrysothamnus viscidiflorus*	Green rabbitbrush
coca	*Conyza canadensis*	Canada horseweed
conu	*Coldenia nuttallii*	Nuttall coldenia
crac	*Crepis acuminata*	Tapertip hawksbeard
crba	*Crepis bakeri*	Bakers hawksbeard
debi	*Delphinium bicolor*	Low larkspur
depi*	*Descurainia pinnata*	Pinnate tansymustard
deso*	*Descurainia sophia*	Flixweed tansymustard
drve2*	*Draba verna*	Spring draba
elan	*Elaeagnus angustifolia*	Russian olive
elci*	*Elymus cinereus*	Basin wildrye
elju*	*Elymus junceus*	Russian wildrye
eppa*	*Epilobium paniculatum*	Autumn willowweed
eran	*Erigeron annuus*	Annual fleabane
erci*	*Erodium cicutarium*	Cutleaf filaree
ergl	*Erigeron glabellus*	Smooth fleabane
ersh*	*Eriogonum shockleyi*	Shockley buckwheat
ervi	*Eriogonum vimineum*	Vim eriogonum
gisi	*Gilia sinuata*	Largeleafrosy gilia
grsp*	*Grayia spinosa*	Spiny hopsage
gusa*	*Gutierrezia sarothrae*	Broom snakeweed
hagl*	*Halogeton glomeratus*	Halogeton
hean*	*Helanthus annuus*	Common sunflower
ivax*	*Iva axillaris*	Rag sumpweed
jubu	*Juncus bufonius*	Toad rush
koam	*Kochia americana*	Greenmolly summercypress
kopr*	*Kochia prostrata*	Forage kochia
kosc*	*Kochia scoparia*	Belvedere summercypress
lapu	*Languloisia punctata*	Great basin langloisia
lare*	*Lappula redowskii*	Redowski tickseed
lase*	*Lactuca serriola*	Prickly lettuce
lepa*	*Lepidium papilliferum*	Idaho pepperweed
lepe*	*Lepidium perfoliatum*	Clasping pepperweed
libu*	*Lithophragma bulbifera*	Bulbous woodlandstar
lodi*	*Lomatium dissectum*	Fernleaf biscuitroot
logr*	*Lomatium grayii*	Biscuitroot
lupu	*Lupinus pusillus*	Low lupine

Appendix A. Continued

Acronym	Scientific Name	Common Name
lysa*	*Lythrum salicaria*	Purple loosestrife
maca*	*Machaeranthera canescens*	Hoary machaeranthera
magl	*Madia glomerata*	Cluster tarweed
meal*	*Mentzelia albicaulis*	Whitestem blazingstar
mesa*	*Medicago sativa*	Alfalfa
mesp*	*Mentha* spp.	Cultivated mint
migr*	*Microsteris gracilis*	Slender falsephlox
myar*	*Myosurus aristatus*	Bristle mousetail
mymi	*Myosotis micrantha*	Smallflower forgetmenot
nadi	*Naverretia divaricata*	Divaricate navarretia
oebo*	*Oenothera boothii*	Evening primrose
orhy*	*Oryzopsis hymenoides*	Indian ricegrass
peac*	*Penstemon acuminatus*	Penstemon
phac*	*Phlox aculeata*	Sagebrush phlox
phho*	*Phlox hoodii*	Hoods phlox
plsc	*Plagiobothrys scouleri*	Scouler popcornflower
plte	*Plagiobothrys tennellus*	Slender popcornflower
poav	*Polygonum aviculare*	Prostrate knotweed
pose*	*Poa secunda*	Sandberg bluegrass
putr*	*Purshia tridentata*	Bitterbrush
rate*	*Ranunculus testiculatus*	Bur buttercup
rucr	*Rumex crispus*	Curly dock
sado*	*Salvia dorrii*	Purple sage
saex*	*Salix exigua*	Coyote willow
saib*	*Salsola iberica*	Saltwort
save*	*Sarcobatus vermiculatus*	Black greasewood
sehy*	*Senecio hydrophyllus*	Senecio
sial*	*Sisymbrium altissimum*	Tall tumblemustard
sihy*	*Sitanion hystrix*	Bottlebrush squirreltail
spcr*	*Sporobolus cryptandrus*	Sand dropseed
spmu*	*Sphaeralcea munroana*	Munro globemallow
stco*	*Stipa comata*	Needleandthread grass
stth*	*Stipa thurberiana*	Thurber needlegrass
suin*	*Suaeda intermedia*	Intermediate seepweed
taas*	*Taeniatherum asperum*	Medusahead
taof	*Taraxicum officinale*	Common dandelion
teca*	*Tetradymia canescens*	Gray horsebrush
tegl*	*Tetradymia glabrata*	Litteleaf horsebrush

Appendix A. Continued

Acronym	Scientific Name	Common Name
tofl*	*Townsendia florifer*	Gray showy townsendia
tradu*	*Tragopogon dubius*	Yellow salsify
trag	*Trifolium agrarium*	Hop clover
trdu	*Trifolium dubium*	Clover
trma	*Trifolium macrocephalum*	Bighead clover
veth	*Verbascum thapsus*	Flannel mullein
vumi*	*Vulpia michrostachys*	Sixweeks fescue
vuoc*	*Vulpia octoflora*	Sixweeks fescue
zypa*	*Zygadenus paniculatus*	Foothill death camas

Appendix B. Habitat classes determined from vegetation surveys on the Snake River Birds of Prey Area, 1987-1992.

1. Shrublands

A. High Density Shrub (Cover > 25%)
   1. Sagebrush
   2. Shadscale
   3. Winterfat
   4. Greasewood
   5. Budsage
   6. Nuttall's Saltbush
   7. Green Rabbitbrush
   8. Gray (Rubber) Rabbitbrush
   9. Spiny Hopsage
   0. Four-Winged Saltbush
   a. Littleleaf Horsebrush

B. Medium Density Shrub (Cover > 5% and <=25%)
   1. Sagebrush
   2. Shadscale
   3. Winterfat
   4. Greasewood
   5. Budsage
   6. Nuttall's Saltbush
   7. Green Rabbitbrush
   8. Gray (Rubber) Rabbitbrush
   9. Spiny Hopsage
   0. Four-Winged Saltbush
   a. Littleleaf Horsebrush

D. High Distubance Regions (Characterized by Russian Thistle)
(Cheatgrass >25%)
   1. Russian Thistle >15%; Native Grasses >25%
   2. Russian Thistle >15%; Native Grasses <25%

(Cheatgrass <25%)
   3. Russian Thistle 15-35%; Native Grasses >25%
   4. Russian Thistle >35%; Native Grasses <25%
   5. Russian Thistle >35%; Native Grasses >25%
   6. Russian Thistle 15-35%; Native Grasses >25%

2. Grasslands

A. Low Disturbance (Cheatgrass < 25%)
   1. Native Grasses > 25%
   2. Native Grasses < 25%

B. High Disturbance (Cheatgrass > 25%)
   1. Native Grasses > 25%
   2. Native Grasses < 25%

Short Term Influence of Tracked Vehicles on Vegetation of the Snake River Birds of Prey National Conservation Area.

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ANNUAL SUMMARY

The purpose of this study was to determine the short-term influence of tracked vehicles on vegetative, exotic annual, and cryptobiotic crust ground cover, and species richness and diversity in the SRBOPNCA.

*Species richness was not affected by tracking type. Diversity (Hill's diversity index) was significantly greater on divoted areas in burned big sagebrush (**Artemisia tridentata**) habitat and on tracked areas in big sagebrush habitat. Total vegetative cover was reduced on divoted areas in burned habitat and on tracked and divoted areas in big sagebrush habitat. Exotic annual cover was not significantly affected by tracking in burned habitat. In big sagebrush habitat, however, both tracking and divoting significantly increased cover of exotic annuals. Cover of lichens, mosses, and total crust (lichens+mosses) was significantly reduced on divoted areas in both burned and big sagebrush habitats.*

INTRODUCTION

Long-term military activities in the Orchard Training Area (OTA) within the Snake River Birds of Prey National Conservation Area (SRBOPNCA) have created concerns about habitat and prey communities (Knick 1992). Tracking by armored military vehicles may influence vegetation directly (Shaw and Diersing 1990) and prey and raptor communities indirectly. One objective of Study 5 is to determine effects of tracking on vegetation by analysis of percent cover of tracking found on randomly located plots (Knick 1992). Tracking date, however, is unknown, thus confounding data analysis and interpretation.

Study 4 sites within the OTA in big sagebrush habitat (2 sites) and burned big sagebrush habitat (2 sites) (hereafter referred to as burned habitat) were tracked in 1992 (designed experiment), and the burned habitat sites were tracked accidentally a second time in 1993. These sites provided an opportunity to study the influence of tracking on vegetation dynamics on highly disturbed areas with relatively high ground cover of exotic annuals (burned habitat) vs. relatively low disturbance areas with few exotic annuals (big sagebrush habitat).

The purpose of this study was to determine the short-term influence of tracked vehicles on vegetative, exotic annual, and cryptobiotic crust ground cover, and plant species richness and diversity in the SRBOPNCA where intensive tracking has occurred and the tracking date is known.

OBJECTIVES

1. Assess the short term influence of tracked vehicles on vegetation and cryptobiotic crusts in big sagebrush and burned habitats.

2. Determine whether ground disturbance caused by tracking provides a source of sites for exotic annual invasion into big sagebrush and burned habitats.

STUDY SITES

Four sites in the OTA used by Study 4 (9a, 9b, 10a, and 10b) were tracked by an M-1 tank during 26-27 June, 1992, as part of the Study 4 Townsend's ground squirrel (*Spermophilus townsendii*) habitat relationship study (Van Horne et al. 1992), and were used for this tracked vehicle impact study. Tracking direction was east-west, and turns were inside the sites. Sites 10a and 10b were tracked accidentally a second time in August-September 1993 (Dana Quinney, IDARNG, pers. commun.). All 4 sites are grazed seasonally by livestock. Each of these 9-ha sites had 25 stakes spaced 75 m apart in a grid pattern 5 stakes long (300 m) by 5 stakes wide (300 m) and oriented north/south and east/west.

Two of the sites were in burned habitat (10a and 10b), and 2 were in big sagebrush habitat (9a and 9b). Vegetation ground cover on big sagebrush sites was dominated by big sagebrush, Sandberg's bluegrass (*Poa secunda*), and bur buttercup (*Ranunculus testiculatus*), whereas on burned sites it was dominated by Sandberg's bluegrass and Russian thistle (*Salsola iberica*) (Van Horne et al. 1991). Cheatgrass (*Bromus tectorum*) was present in small amounts on the burned sites but was absent on the big sagebrush sites.

METHODS

Vegetation Sampling

We sampled vegetation with both ocular point frames (36 points) and quadrats (0.5 X 1.0 m for both). Quadrat data were used to determine species richness because point frames may underestimate the number of species present (Bonham 1989). Point frame data, less subjective than quadrat data, were used to determine cover and Hill's diversity index.

We located plots on the tank track and divoted (area where one tread had been stopped or greatly slowed to make a sharp turn) closest to a random distance (5-30 m) and direction (inside the site perimeter) from the exterior posts marking the east and west ends of each Study 4 site (a total of 10 posts). We laid a series of 5 quadrats and point frames end to end (total distance = 5 m) along a tank track (track width is 0.5 m across the rubber pads, and 0.65 m from 1 edge of the metal to the other edge) or divot. Quadrats were placed first and the data recorded, followed by point frames placed on the same area. A second series of 5 quadrats and point frames were placed 2 m to one side (random) of the first series to sample untracked vegetation. Because the 1992 tracking was difficult to distinguish on sites 10a and 10b, only the 1993 accidental tracking was quantified on these sites.

Data Analysis

The null hypotheses tested were: Vegetative cover, exotic annual cover, cryptobiotic crust ground cover, species richness, and Hill's diversity index are similar between tracked, nontracked, divoted, and nondivoted areas. Quadrat data was used to test species richness; point frame data was used to test cover and Hill's diversity index. We used an alpha value of 0.05 to make all comparisons.

We tested null hypotheses by analysis of variance (Proc GLM, SAS Statistical Institute 1988). The sampling unit was each series of 5 quadrats or point frames. The full model to test the effect of tracking included the habitat (sagebrush, burned sagebrush), habitat replication (site within habitat type), stake (1-10), and tracking type (track, nontrack, divoted, nondivoted) terms, and the habitat*tracking type, habitat replication*tracking type, and stake*tracking type interaction terms. We controlled models for habitat, replication, or stake if the appropriate interaction term was significant. If there was a significant difference between tracking types for a variable, pairwise comparisons were made using the Ryan-Einot-Gabriel-Welsh Multiple Range Test (SAS Institute 1988).

RESULTS

Species Richness

We used the full model to determine the effect of tracking type on species richness, because the habitat*tracking type (P = 0.1454), habitat replication*tracking type (P = 0.1239), and stake*tracking type (P = 0.8354) interaction terms were not significant. There was no significant difference (P = 0.2490) in species richness among tracking types (Table 1).

Hill's Diversity Index

The habitat replication*tracking type (P = 0.4677) and stake*tracking type (P = 0.2593) interaction terms were not significant for diversity. The habitat*tracking type interaction, however, was significant (P = 0.0018). Thus, the model was controlled for habitat. There were significant differences in diversity among tracking types in burned sagebrush (P = 0.0079) and sagebrush habitats (P = 0.0001), so pairwise comparisons were made among tracking types for each habitat.

In burned habitats, divoted areas had significantly greater (P < 0.05) diversity than non-divoted, tracked, and non-tracked areas (Table 2). In big sagebrush habitats, tracked areas had significantly greater (P < 0.05) diversity than non-tracked, divoted, and non-divoted areas.

Total Vegetative Cover

The habitat*tracking type interaction was significant (P = 0.0005) for total vegetative cover. The habitat replication*tracking type (P = 0.3779) and stake*tracking type (P = 0.9985) interactions were not significant. Thus, the model was contolled for habitat. There were significant differences in total vegetative cover among tracking types in burned sagebrush (P = 0.0001) and sagebrush habitats (P = 0.0001), so pairwise comparisons were made among tracking types for each habitat.

Total vegetative cover was significantly lower (P < 0.05) on divoted areas than on non-divoted, tracked, and non-tracked areas in burned habitat (Table 3). In big sagebrush habitat, total vegetative cover was significantly lower (P < 0.05) on divoted areas than on non-divoted, tracked, and non-tracked areas; total vegetative cover on tracked areas was significantly lower (P < 0.05) than on non-tracked and non-divoted areas.

Exotic Annual Cover

The habitat replication*tracking type (P = 0.6161) and stake*tracking type (P = 0.9308) interaction terms were not significant for cover of exotic annuals. The habitat*tracking type interaction, however, was significant (P = 0.0266). Thus, the model was controlled for habitat. There were no significant differences (P = 0.0506) among tracking

Table 1. Species richness by tracking type at 4 sites in the OTA sampled in 1994.

Tracking Type	N Obs	Minimum	Maximum	Mean	Std Error
Nontrack	40	4	10	6.70	0.25
Nondivoted	40	3	10	6.65	0.23
Track	40	4	9	7.15	0.21
Divoted	40	3	9	6.58	0.24

Table 2. Diversity by habitat and tracking type at 4 sites in the OTA sampled in 1994.

Habitat	Type	N Obs	Minimum	Maximum	Mean	Std Error	Pairwise[a]
Burned	Nontrack	20	1.00	3.95	1.96	0.17	B
	Nondivoted	20	1.04	3.39	2.01	0.16	B
	Track	20	1.00	3.98	2.04	0.19	B
	Divoted	20	0.00	4.74	2.67	0.27	A
Sage	Nontrack	20	1.28	3.59	1.89	0.15	B
	Nondivoted	20	1.36	3.26	2.10	0.10	B
	Track	20	1.07	4.25	2.92	0.18	A
	Divoted	20	1.07	4.43	2.18	0.20	B

[a]Ryan-Einot-Gabriel-Welsch Multiple Range Test. Means within a habitat class with the same letter are not significantly different.

Table 3. Total vegetative cover by habitat and tracking type at 4 sites in the OTA sampled in 1994.

Habitat	Type	N Obs	Minimum	Maximum	Mean	Std Error	Pairwise[a]
Burned	Nontrack	20	0.56	66.67	40.33	3.53	A
	Nondivoted	20	15.00	56.67	33.56	2.72	A
	Track	20	9.44	71.67	39.61	3.78	A
	Divoted	20	0.00	40.00	18.53	2.61	B
Sage	Nontrack	20	29.44	73.89	51.64	3.37	A
	Nondivoted	20	38.33	73.33	53.17	2.18	A
	Track	20	18.33	51.67	35.19	2.13	B
	Divoted	20	7.22	33.89	21.28	1.75	C

[a]Ryan-Einot-Gabriel-Welsch Multiple Range Test. Means within a habitat class with the same letter are not significantly different.

types in burned sagebrush habitats (4). There were, however, significant differences in cover of exotic annuals among tracking types in sagebrush habitats ($P = 0.0001$), so pairwise comparisons were made among tracking types for each habitat.

In big sagebrush habitats, divoted areas had significantly greater ($P < 0.05$) exotic annual cover than non-divoted, tracked and non-tracked areas; tracked areas had significantly greater ($P < 0.05$) exotic annual cover than non-tracked and non-divoted areas (Table 4).

Cryptobiotic Crust Cover

Lichens.-- The habitat*tracking type interaction ($P = 0.0812$), habitat replication*tracking type ($P = 0.2703$), and stake*tracking type ($P = 0.8869$) interactions were not significant for cover of lichens. Thus, the full model was used to test for differences in lichen cover among tracking types. There were significant differences in lichen cover among tracking types ($P = 0.0001$) so pairwise comparisons were made among tracking types.

Lichen cover on divoted areas was significantly lower ($P < 0.05$) than on non-divoted, tracked, and non-tracked areas (Table 5).

Table 4. Exotic annual cover by habitat and tracking type at 4 sites in the OTA sampled in 1994.

Habitat	Type	N Obs	Minimum	Maximum	Mean	Std Error	Pairwise[a]
Burned	Nontrack	20	0.00	41.67	14.25	2.79	-
	Nondivoted	20	0.56	38.33	10.58	2.12	-
	Track	20	1.11	53.89	20.44	3.38	-
	Divoted	20	0.00	33.89	12.83	2.07	-
Sage	Nontrack	20	0.00	13.33	4.92	0.94	C
	Nondivoted	20	0.00	18.89	4.28	1.24	C
	Track	20	0.56	30.56	9.56	1.80	B
	Divoted	20	0.00	33.33	13.94	2.31	A

[a]Ryan-Einot-Gabriel-Welsch Multiple Range Test. Means within a habitat class with the same letter are not significantly different.

Table 5. Lichen cover by tracking type at 4 sites in the OTA sampled in 1994.

Type	N Obs	Minimum	Maximum	Mean	Std Error	Pairwise[a]
Nontrack	40	0.00	17.22	3.49	0.59	A
Nondivoted	40	0.00	16.67	3.51	0.57	A
Track	40	0.00	11.67	2.90	0.50	A
Divoted	40	0.00	2.22	0.32	0.08	B

[a]Ryan-Einot-Gabriel-Welsch Multiple Range Test. Means with the same letter are not significantly different.

Mosses.-- The habitat*tracking type interaction ($P = 0.0509$), habitat replication*tracking type ($P = 0.1601$), and stake*tracking type ($P = 0.6430$) interactions were not significant for cover of mosses. Thus, the full model was used to test for differences in moss cover among tracking types. There were significant differences in moss cover among tracking types ($P = 0.0001$) so we made pairwise comparisons among tracking types.

Moss cover on divoted areas was significantly lower ($P < 0.05$) than on non-divoted, tracked, and non-tracked areas (Table 6).

Total Crust (Lichens+Mosses). -- The habitat*tracking type interaction was significant ($P = 0.0116$) for total vegetative cover. The habitat replication*tracking type ($P = 0.1153$) and stake*tracking type ($P = 0.8690$) interactions were not significant. Thus the model was contolled for habitat. There were significant differences in total vegetative cover among tracking types in burned sagebrush ($P = 0.0123$) and sagebrush ($P = 0.0.0001$) habitats, so pairwise comparisons were made among tracking types for each habitat.

In burned habitats, total cryptobiotic crust cover on divoted areas was significantly lower ($P < 0.05$) than on non-tracked areas, but was similar ($P > 0.05$) to that on non-divoted and tracked areas (Table 7). In big sagebrush habitat, total cryptobiotic crust cover on divoted areas was significantly lower ($P < 0.05$) than on non-divoted, tracked, and non-tracked areas (Table 5).

Table 6. Moss cover by tracking type at four sites in the OTA sampled in 1994.

Type	N Obs	Minimum	Maximum	Mean	Std Error	Pairwise[a]
Nontrack	40	0.00	46.67	7.39	1.36	A
Nondivoted	40	0.00	24.44	5.97	1.00	A
Track	40	0.00	20.56	4.72	0.87	A
Divoted	40	0.00	10.56	1.35	0.37	B

[a]Ryan-Einot-Gabriel-Welsch Multiple Range Test. Means with the same letter are not significantly different.

Table 7. Cryptobiotic crust cover by habitat and tracking type at 4 sites in the OTA sampled in 1994.

Habitat	Type	N Obs	Minimum	Maximum	Mean	Std Error	Pairwise[a]
Burned	Nontrack	20	0.00	22.22	7.81	1.52	A
	Nondivoted	20	0.00	15.56	5.19	1.09	AB
	Track	20	0.00	15.00	3.58	1.00	AB
	Divoted	20	0.00	11.11	1.75	0.73	B
Sage	Nontrack	20	0.56	50.56	13.94	2.75	A
	Nondivoted	20	1.67	32.22	13.78	1.87	A
	Track	20	1.67	25.00	11.67	1.48	A
	Divoted	20	0.00	6.11	1.58	0.42	B

[a]Ryan-Einot-Gabriel-Welsch Multiple Range Test. Means within a habitat class with the same letter are not significantly different.

DISCUSSION

Species Richness

Tracking by armored military tracked vehicles did not affect species richness significantly. Apparently, species destroyed by tracking are replaced by new species that quickly exploit the open site.

Hill's Diversity Index

Significantly greater diversity on tracked and divoted areas vs. non-tracked and non-divoted areas whereas species richness is similar between areas suggests that evenness must be greater on tracked and divoted areas.

Total Vegetative Cover

The fact that only divoted areas had significantly lower total vegetative cover in burned habitat suggests that it takes very high disturbance to lower total vegetative cover on areas that are already disturbed. In sagebrush habitat, the influence of tracking and divots was much more pronounced. Thus, the potential damage from tracked vehicle movement may be greater in sagebrush habitat than in burned habitat.

Exotic Annual Cover

Exotic annual cover increases were not marked on tracked and divoted areas in burned habitat. Less than 1 year between sampling date and tracking date was apparently too short a time period to allow extensive colonization by exotic annuals. Additionally, the already high cover of exotic annuals in burned habitat limits possible increase in cover. The significant increase in exotic annual cover on tracked and divoted areas in big sagebrush habitat suggests that these areas may be very sensitive to tracking. These disturbed areas may return to sagebrush habitat through secondary succession if they do not burn. Increased exotic annual cover on tracked areas in big sagebrush, however, increases the likelihood of fire and further reduction in big sagebrush habitat.

Cryptobiotic Crust Cover

Cover of cryptobiotic crusts may be important to nitrogen cycling, soil stabilization, and total ecosystem function. Thus, significant reductions in cryptobiotic crusts on divoted areas in burned sagebrush and sagebrush habitats suggest that creation of divots should be especially discouraged in all habitats.

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Use of Satellite Imagery to Delineate Habitats in the Snake River Birds of Prey National Conservation Area

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ANNUAL SUMMARY

We continued production of the vegetation map for the Integration Study Area from translation of satellite imagery for the BLM/IDARNG Research Project. In 1994, we completed translations for quadrangles south of the Snake River. After inspection for regions with clustered errors, we used a regional data set to translate quadrangles in the northeastern portion of the Integration Study Area. In field surveys, we collected vegetation samples in the Hammett region of the Snake River Birds of Prey National Conservation Area. These vegetation samples will be used to develop a calibration set for translating that region in 1995.

OBJECTIVES

1. To develop a habitat classification for the Snake River Birds of Prey National Conservation Area.
2. To determine the relationship between vegetation and spectral qualities in Thematic Mapper satellite imagery.

3. To create a vegetation map from satellite imagery for the Snake River Birds of Prey National Conservation Area.

INTRODUCTION

Accurate maps of habitats are essential for relating organisms to spatial elements in the environment. Until recently, habitat maps were created by interpreting aerial photographs or by intensive ground-based sampling. Computer software for image processing coupled with Geographic Information Systems now permit creation of habitat maps from satellite images.

Remote sensing of the earth from satellite platforms is emerging as a powerful tool to obtain fine-grained information for large regions (Roughgarden et al. 1991). Data from satellites, when correlated with ground characteristics, can be used to assess vegetative cover (Richardson and Wiegand 1977, Tucker 1979, Running et al. 1989), quantify habitats used by wildlife (Robertson et al. 1990, Shaw and Atkinson 1990), describe landscape features (Milne 1992), and detect temporal change in earth resources (Hall et al. 1991, Price et al. 1992).

Delineation and analysis of forested regions and agricultural croplands by satellite imagery has been successful. However, habitats in rangelands and other arid ecosystems are more difficult to delineate because the ground cover of vegetation and photosynthetic material is relatively low compared to other influences, such as soil reflectance, on spectral quality (Ustin et al. 1985, Tueller 1987). Spectral responses in satellite imagery also are less sensitive to desert vegetation because the relatively simple vegetative structure has minimal influence on reflective and refractive radiation.

In this report, we discuss our progress in developing a vegetation map for the Integration Study Area, within the Snake River Birds of Prey National Conservation Area. This effort involves interaction of field surveys and computer analyses in image processing and Geographical Information Systems (Knick et al. 1991, Knick et al. 1992a, b, Knick et al. 1993).

METHODS

Study Area

The Snake River Birds of Prey National Conservation Area (SRBOPNCA) (116° E Long, 43° N Lat) includes approximately 195,325 ha of desert rangeland in the Snake River Plain, southwestern Idaho. Once predominantly shrubland, approximately one-half of the shrubland in the SRBOPNCA has burned since 1975 and is now dominated by cheatgrass (*Bromus tectorum*) and Russian thistle (Kochert and Pellant 1986). Big sagebrush (*Artemisia tridentata*) communities dominate the region in the north and grade into salt shrub communities in the south (Yensen and Smith 1983). Livestock grazing and military training are the primary land-use activities (Kochert and Pellant 1986). Weather in the SRBOPNCA is characterized by hot, dry summers and cold winters. Maximum daily temperature from 1955 to 1989 averaged 30-36 C during June-August and 5-9 C during December-January at the Swan Falls weather station, and annual precipitation at this site averaged 26.9 cm.

Image Translation

Methods used to translate satellite imagery were described in Knick et al. (1992a, 1993). Accuracy of this method and sources of error are currently in preparation for publication.

Image Translation South of the Snake River.--We translated the satellite images into vegetation classes (Knick et al. 1993) for complete quadrangles in the Integration Study Area, south of the Snake River. A second calibration set of vegetation data was developed from samples collected south of the Snake River. The calibration set included 689 samples. The separate calibration set was necessary because of differences in vegetation, soils and reflectance, and image characteristics from the region north of the Snake River.

Image Translation for the Northeastern Integration Study Area.--We retranslated the satellite images in the northeastern portion of the

Integration Study Area after consultation with Study 1 of the BLM/IDARNG Research Project. We developed the set of calibration data from sites with known vegetation samples in the region east of Simco Road and north of the Mountain Home Air Force Base. Our purpose was to reduce errors created by regional variation in the calibration set. Error assessment for this region is currently under analysis.

PLANS FOR NEXT YEAR

We will complete a final translation of the vegetation map for the Integration Study Area. Also in 1995, we will complete a vegetation map for the entire SRBOPNCA, including the eastern region. We currently are preparing a manuscript for publication that details our methods and accuracy of the vegetation map.

We are testing the feasibility of a regional approach to translating images for the entire SRBOPNCA. In this method, we will use calibration data only from sites <10-15 km from a quadrangle boundary. This moving window potentially will permit development of individual calibration sets more specific for an area and reduce variation caused by using extant regional sites to delineate local characteristics.

We will use the vegetation map and satellite images for analyses of raptor foraging and prey distribution. In addition, we will examine landscape patterns, such as fractal dimensions (Milne 1988, 1992; Palmer 1992), to explain distribution and abundance of shrubsteppe passerine birds (Knick and Rotenberry 1995) and black-tailed jackrabbits (*Lepus californicus*). Relationship of other species to landscape patterns also will be analyzed when data are available. Studies of landscape patterns offer potential for determining the impact of land-use practices on habitats, as well as insight into the scale at which species respond to their habitats (Wiens 1989).

ACKNOWLEDGMENTS

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Integration Activities for the BLM/IDARNG Project - 1994

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ANNUAL SUMMARY

Principal accomplishments of the 1994 Research Project Integration effort included review of 1994 annual reports for each component study, review and analysis of grazing effects in the region, development of a list of research products resulting from the research effort and an outline of a Final Research Report, organizing a meeting to discuss future biological monitoring activities, and organizing a Project Integration Workshop.

OBJECTIVES

1. Provide coordination and quality control for the overall research project.
2. Develop a conceptual model that relates the impacts under study (military activities, grazing, and fire) to trophic level relationships (soils/vegetation, prey, raptors).
3. Develop and maintain the Digitized Resource Data Base Map throughout the course of the overall research project, and use it to support the field effort.

4. Provide support for analysis and preparation of documents concerning impact analysis. management and monitoring of the SRBOPNCA consistent with the results of the research.

MAJOR ACCOMPLISHMENTS

Many of the following accomplishments were completed by the Integration staff of the Raptor Research and Technical Assistance Center of the National Biological Survey, particularly Steven Knick, Michael Kochert, Karen Steenhof, and Thomas Zarriello. Research Project principal investigators (PI's) also contributed.

1. Karen Steenhof reviewed draft 1994 annual reports for research continuity, appropriateness of analytical techniques, and possible data integration problems. Problems identified in study details or direction were corrected, and these corrections were incorporated into the revised annual reports that appear in this volume.

2. Dr. Stefan Sommer, Idaho State University, completed a review of livestock grazing effects in intermountain shrubsteppe ecosystems, including an annotated bibliography of relevant grazing literature. Dr. Sommer also completed a report summarizing extant BLM data on distribution of livestock and grazing effects on the Snake River Birds of Prey National Conservation Area (SRBOPNCA) and the Bruneau Resource Area, and prepared a draft report (which is still in review) of an analysis of grazing exclosure vegetation data taken from the SRBOPNCA. Integration staff reviewed drafts of documents and provided additional input.

3. Michael Kochert organized and chaired a meeting held 8 March 1994 to discuss long-term monitoring of raptors, prey, and vegetation to be implemented at the conclusion of the current research project. At a subsequent meeting held on 27 July 1994 we identified interim monitoring priorities for the SRBOPNCA.

4. We held brief integration meetings on 9 March and 26 July 1994 to discuss integration study plans and remaining tasks to be completed during 1994. At the second meeting we decided to prepare an integrated Final Research Report rather than individual study final reports (see item 7 below).

5. Integration staff and principal investigators developed a detailed list of research products, which consist of manuscripts (either published, in press, submitted, or in completed draft in preparation for submission), selected SRBOPNCA Annual Reports, and any other unpublished reports, lists or tables, etc., that will be generated by individuals study PI's and their staffs or as collaborative analysis and interpretation among study PI's and staff (e.g., work groups; see item 6 below). These will provide supporting documentation for the Final Research Report.

6. Integration staff and principal investigators developed six Work Groups arranged around the 10 Research Questions and the basic elements of the Integration Model. Work groups are responsible for analysis and write-ups of various components of the research, including habitat map, jackrabbits, ground squirrels, prey distribution and raptor habitat use, raptor distribution, abundance, and productivity, and raptor nest site distribution.

   There is broad overlap in work group membership among the PI's, individual studies' staff, and RRTAC staff, and most groups are now arranged around Final Research Report chapters (see item 7 below). Idaho Army National Guard environmental personnel also participate.

7. Integration staff and principal investigators developed and revised an outline of a Final Research Report that will represent an academic synthesis or integration of all research done as part of the project. It will be submitted to BLM, NBS, and the National Guard, and will likely form the basis for any report prepared by them for the Secretary of the Interior or U.S. Congress. It will deal with research findings and management and monitoring recommendations based on the results of that research and management goals provided by BLM or the NCA legislation.

8. A Study Integration Workshop was held at the U.S. Geological Survey Boise District Office, 15-17 November 1994. The principal product of this workshop was a revised and greatly expanded draft outline for the Final Research Report. Each of 15 sections was worked on by 3-10 people for 1-3 hours each.

   All work group products were then combined and edited into a single document, which has been distributed to all for comment and review. We also developed a timetable for future integration activities.

9. In consultation with integration staff and principal investigators, Rotenberry developed and periodically updated a detailed timeline of significant events and deadlines to help keep the project on schedule towards the 31 March 1996 completion date.

10. The draft plan for the computer simulation of habitats, prey, and raptors was completed and revised after a meeting of Integration staff in March. Algorithms were developed for climate, burn, and vegetation regeneration submodels within the habitat module, and for the Townsend's ground squirrel module. Brett Hoover, of the National Biological Survey, Patuxent, MD was contracted to program the simulation.

PLANS FOR NEXT YEAR

1. Integration staff will continue to provide coordination and quality control in consultation with component study principal investigators and the Technical Advisory and Review Panel. We will also hold another integration workshop, nominally around 15 March 1995, whose main agenda will be a progress report from integration work groups.

2. Staff will continue to develop of an overall integration model, incorporating as its basis the conceptual system model outlined in the Research Plan. The lead for overall model development lies with the Integration staff, particularly Dr. Steven Knick of RRTAC. He will be assisted by Gail Olson, Colorado State University, and Brett Hoover, National Biological Survey.

3. Integration staff will participate in a statistical workshop in January 1995 presented by Dr. Brian Cade, National Biological Survey, and arranged by Dr. John Marzluff, Study 2.

4. Michael Kochert will coordinate a meeting among Project principal investigators to develop methods for continuing biological monitoring throughout the SRBOPNCA beyond the Project end date. We will continue to develop a plan for long-term monitoring of raptors, prey, and vegetation to be implemented at the conclusion of the current research project.

5. The first draft of the Final Research Report is scheduled to be completed by 31 May 1995, with a revision due 31 July 1995. At that time, all studies will officially be over. Any final individual study project reports are due to appropriate sponsors then as well. We will continue to revise the Final Research Report until its due date of 31 March 1996.

6. John Rotenberry will continue to update a detailed timeline of future events and deadlines to help keep the project on schedule towards the 31 March 1996 completion date.

Each of the preceding activities will be assigned to one or more members of the Integration Team, who will be responsible for its timely completion. These assignments will be discussed early during the 1995 calendar year.

Influences of Ectoparasites (Hemiptera: Cimicidae) on the Hematology of Nestling Prairie Falcons

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ANNUAL SUMMARY

*Infestations of hematophagous ectoparasites in prairie falcon (**Falco mexicanus**) aeries prompted me to investigate their influences on nestling health. In 1993 and 1994 I sampled blood from nestling prairie falcons to determine hematocrit, an indicator of anemia, and other hematological values. Hematocrit values were significantly lower for nestlings occupying moderate to heavily infested aeries than for nestlings occupying non-infested or lightly infested aeries. Nestlings with lower hematocrit values were lighter in weight than nestlings with higher hematocrit values. The ectoparasites were identified as **Haematosiphon inodorus** (Hemiptera: Cimicidae), commonly known as Mexican chicken bugs.*

OBJECTIVES

1. Determine the effects of hematophagous ectoparasites (Cimicids) on the health of prairie falcon nestlings by hematological investigation.

2. Provide baseline hematological values for wild prairie falcon nestlings.

INTRODUCTION

Cimicid bugs have been implicated as the cause of death for many nestling raptors. Mexican chicken bugs (*Haematosiphon inodorus*), ectoparasites belonging to the family Cimicidae, have been blamed for the deaths of nestling bald eagles (*Haliaeetus leucocephalus*; Grubb et al. 1984), prairie falcons, and red-tailed hawks (*Buteo jamaicensis*; Platt 1975). Usinger (1966) reported several other raptor species as hosts for the Mexican chicken bug. A study conducted by Sitter (1983) at the Snake River Birds of Prey National Conservation Area (SRBOPNCA) concluded that swallow bedbugs (*Oeciacus vicarius*), also members of the Cimicidae family, indirectly caused the deaths of prairie falcon nestlings. McFadzen and Marzluff (1992, 1993) also found that cimicid bugs contributed to the mortality of prairie falcon young. The effects of cimicid bugs on the health or general condition of nestling raptors is not known. Here I present a hematological investigation of nestling prairie falcons that occupied aeries with differing levels of cimicid bug infestations.

METHODS

I sampled blood from 110 prairie falcon nestlings during the latter half of the 1993 breeding season and during the 1994 breeding season. Most of the broods that I sampled were concurrently studied by

the NBS/IDARNG research project in the SRBOPNCA. As nestlings reached 30 days of age, they were retrieved by climbers and processed (see Lehman et al. 1993 and Marzluff et al. 1993 for methods). I withdrew 0.1-1 cc of blood with a syringe from the brachial vein. A portion of the blood was drawn into 2 heparinized capillary tubes and later centrifuged for 15 min at 12,000 rpm to obtain a mean hematocrit value (or packed cell volume, defined as the ratio of packed red blood cells to total blood volume). Blood smears and other blood samples were sent to Dr. Teresa Morishita, Ohio State University, Columbus, but have not been analyzed yet. The level or intensity of cimicid bug infestation in aeries was recorded by climbers. I separated aeries into 2 groups based on level of infestation: group 1 included aeries with no infestation or a light infestation and group 2 included aeries with a moderate to heavy infestation. Bug specimens were collected from aeries and sent to entomologists for examination.

Mean brood hematocrit values and fledging weight were calculated by averaging these variables by sex within a brood. I used ANCOVAs with 1 factor (hematocrit) and 3 covariates (seventh primary length, brood size, and hatching date) to test for differences in male or female fledging weight. Hematocrit had 2 levels based on means for males and females: ≤ and > mean hematocrit value. The influences of ectoparasite loads on hematocrit was tested by using an ANCOVA with the 2 levels of infestation described above and using hatching date as a covariate.

RESULTS AND DISCUSSION

Two cimicid bug specimens from 2 prairie falcon aeries in 1992 and in 1993 were identified as Mexican chicken bugs (McFadzen and Marzluff 1992, D. Baker, Univ. of CA, Davis, pers. commun.). Bug specimens collected from other aeries are currently under examination.

Hematocrit values did not differ with the sex of nestlings. Mean hematocrit values for nestling males per brood ($\bar{x}$=34.3, SE=1.18, n=26 broods) were similar to mean values for nestling females per brood ($\bar{x}$=33.6, SE=0.96, n=24 broods; t=0.46, P=0.68, df=48). Therefore I calculated a mean hematocrit value per brood and compared these mean values between 2 groups of nestlings. Group 1 (n = 23 broods) included nestlings that occupied aeries that were not infested or were lightly infested with cimicid bugs, whereas Group 2 (n = 5 broods) included nestlings from aeries that had moderate to heavy infestations. The mean hematocrit values were significantly lower for broods occupying aeries with heavier ectoparasite loads (adjusted mean hematocrit using hatching day as a covariate: $\bar{x}_{group\ 1}$ = 36.25, SE = 0.53; $\bar{x}_{group\ 2}$ = 30.83, SE = 1.16; $F = 17.79$, $P < 0.001$). Unadjusted hematocrit means are as follows: $\bar{x}_{group\ 1}$ = 35.12, SE = 0.80 and $\bar{x}_{group\ 2}$ = 26.02, SE = 2.23.

The lack of information on hematocrit values for wild nestlings makes interpretation of these results difficult. Redig (1993) reported a mean hematocrit value of 33 and 44.6% for wild red-tailed hawk (*Buteo jamaicensis*) nestlings and healthy captive adults, respectively. The mean hematocrit of adult red-tailed hawks is similar to hematocrit values for wild non-nestling raptors (means ranging from 41.0 - 52.7; Hunter and Powers 1980, Powers et al. 1994) and for captive non-nestling raptors (means ranging from 40.0 - 49.0; Ferrer et al. 1987, Polo et al. 1992). The mean hematocrit value of prairie falcon nestlings from group 1 was very similar to that of the wild red-tailed hawk nestlings. However, group 2's mean hematocrit value was substantially lower than the mean hematocrit for group 1 and the wild nestlings. Campell (1988) reported that a hematocrit value less than 35 indicated anemia in captive birds, but he did not state the ages of the birds sampled. The lower mean hematocrit of nestling red-tailed hawks compared to the adults' hematocrit suggests that anemia in nestlings is probably represented by a hematocrit value lower than 35. Therefore, the very low mean hematocrit of prairie falcon nestlings from group 2 likely indicates anemia whereas the mean hematocrit of group 1 may be within normal limits.

Male and female nestlings with lower hematocrit values were significantly lighter in weight than were males and females with higher values (for males: $F_{1,20} = 8.93$, $P = 0.007$, [adjusted mean weight for lower hematocrit: $\bar{x}_{weight}$ = 518.19, SE = 10.49, n = 9 broods; for higher hematocrit: $\bar{x}_{weight}$ = 557.55, SE = 7.84, n = 16 broods]; for

females: $F_{1,19} = 10.37$, $P = 0.005$, [adjusted mean weight for lower hematocrit: $\bar{x}_{weight} = 743.99$, SE = 14.24, $n = 11$ broods; for higher hematocrit: $\bar{x}_{weight} = 808.94$, SE = 12.99, $n = 13$ broods]).

The results of this study show that 2 health parameters, hematocrit and weight, of prairie falcon nestlings were influenced by the heavier ectoparasite infestations. Previous work conducted on the effects of swallow bedbugs on cliff swallows (*Hirundo pyrrhonota*) have shown similar results. Swallow nestlings from ectoparasitized colonies had lower hematocrit values (Chapman and George 1991), lower fledging weights, and higher nestling mortality than did non-infested colonies (Brown and Brown 1986, Chapman and George 1991).

The role of cimicid bugs in the ecology of the avian community at the SRBOPNCA is not known. To interpret and understand measures of reproductive success and ultimately reproductive fitness, it is imperative to know how and to what degree ectoparasites, as well as other factors such as prey abundance and availability, weather, and human disturbance, affect birds.

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Winter Ecology of Prairie Falcons in the Snake River Birds of Prey National Conservation Area

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ANNUAL SUMMARY

*Prairie falcons (**Falco mexicanus**) winter in the Snake River Birds of Prey National Conservation Area (NCA) on a regular basis, but little is known about their ecology at this time of the year. There appeared to be 2 distinct groups of falcons wintering in the NCA during 1993-94; 37% were known to have bred in the NCA the previous summer, but many of the others may have migrated to the NCA for the winter. We trapped 17 prairie falcons between November 1993 and March 1994. In addition we detected 10 prairie falcons, with radio telemetry, that bred in the NCA during the 1993 breeding season, at various times during the winter. The sex ratio of all falcons present during the winter was male biased (20 males : 7 females). The sex ratio of the 17 individuals trapped, was not significantly different from a 1:1 ratio (11 males : 6 females), whereas the ratio of the 10 falcons remaining from the breeding season was significantly biased towards males (9 : 1). From our trapped sample, we observed hunting attempts by 4 males and 2 females, noted the prior breeding status of the 10 remaining falcons, and determined winter home ranges for 2 males and 3 females. Successful capture attempts suggested that wintering prairie falcons prey mainly on horned larks (**Eromophila alpestris**), though other prey items were taken. Prior productivity did not affect whether individual falcons wintered in the NCA. Winter home ranges of females ($\bar{x}$ = 5,811 ha, SE = 2,394 ha) were not significantly larger than males ($\bar{x}$ = 3,017 ha, SE = 592 ha).*

OBJECTIVES

1. Quantify the sex and age of prairie falcons wintering in the NCA.

2. Document hunting methods and prey selection by prairie falcons wintering in the NCA.

3. Document past and subsequent breeding status of wintering individuals to determine if productivity influences which falcons remain in the NCA during the winter.

4. Define winter home ranges for prairie falcons using minimum convex polygons (MCP) and determine if range size is different between males and females.

INTRODUCTION

The wintering ecology of prairie falcons is poorly documented. The only detailed published research was from Colorado (Enderson 1964, Beauvais et al. 1992). Enderson (1964) found that males outnumbered females, adults were slightly more abundant than juveniles, males had slightly smaller home ranges than females (6.1 km and 11.5 km respectively), and individuals spent much of their time hunting. Beauvais et al. (1992) concentrated on habitat use and the correlation between habitat type and prey availability. They found that home ranges included significantly higher proportions of cultivated land than was available, males significantly outnumbered females, adults and juveniles were trapped in equal numbers, and horned larks appeared to be the dominant prey.

Prairie falcons are regularly seen wintering in the NCA, though numbers vary from year to year (Kochert and Steenhof, NBS-RRTAC, pers. commun.). Marzluff et al. (1991,1992) reported that some falcons that bred in the NCA have been detected throughout the winter. Females as well as males were present, but most individuals were males. Ratios of adults and juveniles have not been documented. They observed these falcons primarily in general areas: 1) perched on power poles in short grassland, sagebrush, and cultivated areas; or 2) in proximity to scattered feedlots. These observations, combined with the knowledge that the NCA has the highest known density of breeding prairie falcons in the world (U.S. Dep. Inter. 1979), prompted us to determine if the prairie falcons that winter in the NCA are: 1) mostly males that bred there; or 2) migrants.

We propose that more male than female prairie falcons winter in the NCA and that they are from 2 separate groups: residents and migrants. Here we begin to address this proposition by summarizing our data collected during the winter of 1993-94. We focused on determining the sex and age of prairie falcons wintering in the NCA, observing their foraging attempts, documenting their breeding status, and calculating winter home ranges.

METHODS

Study area

The study area included a portion of the NCA and was bordered by Simco Road and Highway 67 on the east, Highway 45 on the west, Kuna Mora Road on the north, and the Snake River on the south. Most of the study area is open rangeland with habitat classified as shrubsteppe (Kuchler 1964, Rotenberry and Wiens 1980). Farmland, both active and fallow, borders the northwestern, northern and eastern portions. Big sagebrush (*Artemisia tridentata)* is the predominant shrub in the rangeland. The most common plants occupying the disturbed areas are Russian thistle (*Salsola iberica*) and cheatgrass (*Bromus tectorum;* U.S.Dep. Inter. 1979).

Trapping

We trapped 17 prairie falcons between 31 October and 19 December 1993 using pigeons wearing a leather body harness dorsally fitted with nooses of 25-35 pound test monofilament (Bloom 1987), and bal-chatri traps (Berger and Mueller 1959) baited with starlings (*Sturnus vulgaris*). We trapped along power lines, fence lines, and feed lots with emphasis on, but not limited to, the Idaho Power Line (Big Baha), Swan Falls Road, and the area between the Range Road of the Orchard Training Area (OTA)

and the Snake River canyon. We varied our trapping routes between days and within the routes to avoid unequal trapping efforts on any falcon.

Measurements, Identification and Marking

We weighed individuals to the nearest 5 g with a Pesola scale, measured normal wing chord and wing span to the nearest mm with a folding ruler, and measured foot pad length (edge of hallux pad to edge of middle toe pad) to the nearest mm with calipers. All measurements were taken from the left appendage. We noted each falcon's condition by checking for external parasites, recorded crop content (0-25%, 25-50%, 50-75%, and 75-100%), and recorded general health indexed by the prominence of the keel (1 = lean, 2 = average, 3 = fat). We determined the sex of all individuals using wing chord length (males: 320 mm or less, females: 325 mm or more; U.S. Fish Wildl. Serv. 1991).

We marked all 17 falcons with alpha-alpha anodized aluminum color bands (green: females, blue: males) on the left leg and USFWS bands on the right. Twelve individuals were equipped with radio-transmitters mounted on their backs (3 females; Marzluff et al. 1992), or on their tails (11 males, 3 females). Tail mounts were placed ventrally on the proximal end of the 2 central retrices and anchored with 2 strands of waxed nylon/cotton line and super glue. The antenna was secured to one rachis with 2 strands of dental floss and super glue. Physical characteristics of birds trapped and description of markers are listed in Appendix A.

Observations

We used telemetry and optics to locate instrumented falcons, collect foraging data, and determine winter home ranges. We used a scanning 164/5 MHz receiver, a truck-mounted omnidirectional antenna and a hand-held Yagi antenna to locate and track instrumented falcons. When a falcon was located we used 10 x 50 binoculars and a 60x spotting scope to observe them from the vehicle. We observed falcons from approximately 20 - 80 m, and used the falcon's increased body movements (shifting legs, repeated looks or leaning forward) as cues of disturbance due to our proximity. We adjusted our location to minimize disturbance to the focal bird.

We attempted to locate each radio-tagged falcon every 3 days to determine their winter home ranges, length of stay in the study area and survival. We plotted the locations of falcons on a 1:24,000 United States Geological Survey topographic map. We used Kenward's (1990) Ranges IV to calculate and define winter home ranges by minimum convex polygons (MCP) for 2 male and 3 female prairie falcons. We obtained 22 - 26 fixes for these 5 individuals. We believe this number of fixes is adequate for estimating the winter home ranges for sex-wise comparisons, as indicated by a lack of correlation between winter home range size and number of locations. We determined length of stay from capture date to the day of last sighting or radio contact. We varied our routes to ensure that visual locations were randomly distributed throughout each day.

We conducted focal observations from sunrise to sunset on 3 male and 2 females for a total of 113.4 hours on 13 different days to quantify hunting methods and habitat use. We modified Haak and Jarvis' (1982) classification of 6 hunting methods, condensing them into the following 4 methods:

1) *high stoop* - a high speed, high angle descent from a perch or soaring height (>50 m).

2) *undulating* - a low flight with a slight wave action, between 10 - 25 m above the ground terminating in a quick drop when prey is located.

3) *incline and stoop* - a short flight upwind from a perch to a height of 20 - 30 m followed by a downwind stoop.

4) *perch-originated* - a straight, quick, low angled flight with a hard wingbeat or a low, level flight, with hard wingbeat followed by a glide, quick upward pitch and pursuit of quarry.

We classified a foraging attempt as any of these methods which was directed at, or resulted in, the flush and pursuit of prey (Sherrod 1983). We described attempts by the hunting method, outcome (Beauvais et al.1992), and prey type (to genus) of successful attempts. We further compared hunting methods, relative success, hourly flush rates and hourly rates of secured prey between males and females. We used the site of an attempt (characterized by the flush site) as the center of a 5-m circular plot, to ascribe vegetation characteristics to all attempts. We classified vegetation according to Knick (1993).

Weather Variables

We obtained temperature, wind direction, and wind speed once daily from hourly reports received from the Boise National Airport. Cloud cover was recorded in the field to the nearest 5%. Precipitation and sudden temperature or wind speed changes were noted in the field.

ANALYSES

We used a chi-square goodness-of-fit test to determine if the sex ratio of the 17 prairie falcons we trapped during the winter and the 10 falcons detected at various times during the winter were significantly different from 1:1. We then used a 2 x 2 contingency table (with the Yates continuity correction factor) to test whether the sex ratio of those 10 falcons was equal to the ratio of those individuals radio-tagged during the 1993 breeding season who were not detected during the winter. We used a 4 x 2 contingency table to distinguish any differences between males and females in the use of hunting methods, Wilcoxon rank-sums test to compare relative foraging rates between sexes, and a Mann-Whitney U-test to determine if there was a difference in size of winter home ranges between males and females. We applied a 2 x 2 contingency table (with the Yates continuity correction factor) to test whether prior productivity of prairie falcons that bred in the NCA in 1993 was related to wintering.

RESULTS

Sex Ratio

The sex ratio of all falcons sampled in the NCA during winter 1993-94 was significantly male biased (20:7; $\chi^2 = 6.51$, df = 1, $P = 0.014$). The sex ratio of the 10 falcons known to have bred in 1993 and that we detected during the during the winter, was significantly biased towards males (9:1; $\chi^2 = 4.01$, df = 1, $P = 0.054$) and significantly more male-biased than the sex ratio of 1993 breeders not detected in the study area (14:12; $\chi^2 = 4.15$, df = 1, $P = 0.04$). However, the sex ratio of the 17 birds trapped during the winter did not differ significantly from a 1:1 ratio (11 males: 6 females; $\chi^2 = 1.41$, df = 1, $P = 0.239$).

Foraging Attempts

We found no significant difference in the hunting methods used by males and females ($\chi^2 = 3.87$, df = 3, $P = 0.37$; Fig. 1). Both sexes predominantly method used the perch originated method, (64.7% of 38 attempts by males and 73.6% of 17 attempts by females). Females secured prey on 18% of 17 attempts and males for 16% of 38 attempts. However, males tended to flush more prey per hour ($\bar{X} = 0.25$, $n = 38$, $SE = 0.02$) than did females ($\bar{X} = 0.16$, $n = 17$, $SE = 0.02$; Fig. 2) and secure greater numbers of prey per hour ($\bar{X} = 0.086$, $n = 38$, $SE = 0.002$) than did females ($\bar{X} = 0.067$, $n = 17$, $SE = 0.009$; Fig. 2) ($Z_{flush} = 1.342$, $P = 0.179$; $Z_{prey} = 0.447$, $P = 0.654$). We saw females secure only horned larks, whereas males secured 5 horned larks, 1 kangaroo rat (*Dipodomys* spp.) and 1 unidentified vole; Fig. 3).

Breeding Status

Whether or not a falcon who bred in 1993 was re-encountered in winter 1993-94 was independent of its 1993 nesting success ($\chi^2 = 0.402$, df = 1, $P = 0.53$). Of 17 falcons trapped in the winter of 1993-94, 3 were later captured during spring 1994 in breeding t erritories randomly selected by

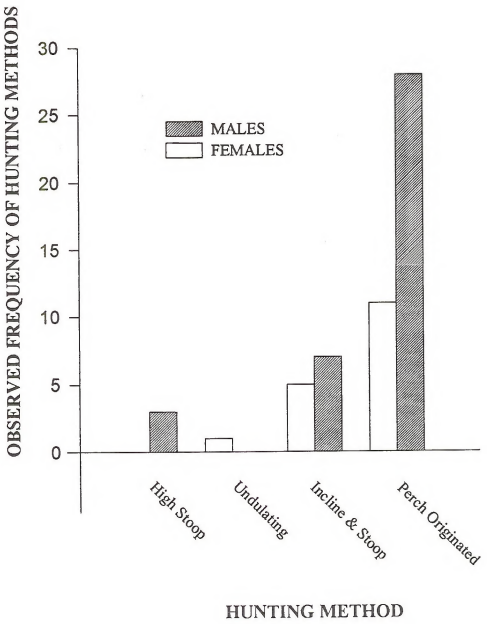

Fig. 1. Frequency of observed hunting methods used by male and female prairie falcons during winter 1993-94. We observed no high stoops by females and no undulating attempts by males.

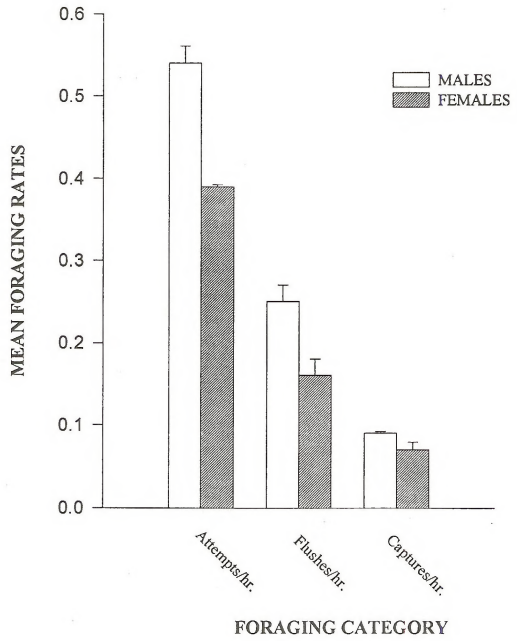

Fig. 2. Foraging rates of male and female prairie falcons wintering in the NCA.

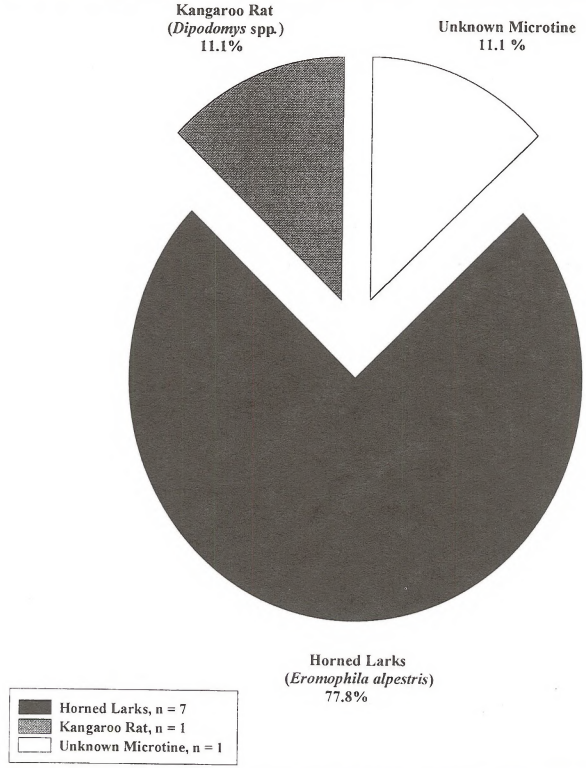

Fig. 3. Observed prey composition of prairie falcons wintering in the NCA, $n = 9$ prey items taken during 55 attempts.

Greenfalk (Marzluff et al. this volume.). The remaining 14 either left at various times during the winter or were undetected by Greenfalk and BLM during the 1994 breeding season.

Winter Home Range

Male and female falcons did not maintain winter home ranges significantly different in size. The average winter home range for males was 3,017 ha (n = 2, range = 2,424 - 3,609 ha, SE = 592 ha). Females maintained an average range of 5,811 ha (n = 3, range = 1,070 - 8,770 ha, SE = 2,394 ha), (Z = 0.288, df = 1, P = 0.773).

DISCUSSION

The combined ratio of all falcons sampled and comparisons of the sex ratios between the 10 falcons detected from the 1993 breeding season and those who were not detected from the 1993 breeding season, strongly suggest that males outnumber females and that a mixture of resident breeders and migrants wintered in the NCA during 1993-94. Comparisons between the groups also suggest that the lack of male bias in the sex ratio of the 17 falcons we trapped may have been influenced by female migrants. Further, the low percentage of the 17 trapped individuals (18%), who were known to breed in 1994, also supports the occurrence of migrants. The remaining 82% either moved to other wintering areas or could not be tracked after their radio transmitters shed. Our trapped sample likely contained residents because 3 of these falcons bred in 1994. A more thorough search of the canyon during the breeding season may have revealed additional breeders from our trapped sample.

Females may be less abundant in the NCA during the winter because females appeared to rely on horned larks more than males. Males exhibited more flushes per hour and secured more prey items per hour than females. Lower numbers of females are not supported by differences in hunting method; all falcons used perch-originated attempts most of the time. Capture rates in the NCA are similar to the 13.5% rate observed in Colorado (Beauvais et al. 1992).

Because the NCA has the highest known density of breeding prairie falcons in the world (U.S. Dep. Inter. 1979), competition for prime breeding territories may influence whether or not falcons winter there. If males are responsible for establishing territories, then the significant male bias present in the group of 1993 breeders that wintered in the NCA may support that theory.

Although there was no correlation between presence of individuals during the winter and prior productivity, it is possible that any relationship between prior productivity and wintering status was obscured by the effect of year; in that productivity in 1993 was significantly lower than in 1992 or 1991 (Marzluff et al. 1993).

PLANS FOR NEXT YEAR

In the winter of 1994-95, we will continue to quantify foraging attempts and to determine winter home ranges. In addition, we will conduct morefull day observations and will include horned lark transects to compare relative habitat use by prairie falcons and horned larks.

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Appendix A. Characteristics of prairie falcons trapped in the NCA during winter 1993-94.

		Color Band							Wing (mm)		
Date	Band No.	Color	Leg	Code	Radio Freq	Sex	Mass	% Crop	Chord	Span	Toe Pad (mm)
27 OCT	NA[a]	BLUE	L	A/A	165.415	M	555	0-25	31	986	81
27 OCT	2206-22877	BLUE	L	A/B	165.585	M	500	0-25	311	976	081
29 OCT	2206-22878	BLUE	L	A/C	165.865[b]	M	518	0-25	314	964	079
31 OCT	2206-22879	BLUE	L	A/D	164.085	M	574	0-25	310	984	082
03 NOV	1807-47702	GREEN	L	6/3	165.535	F	901	0-25	351	1112	097
05 NOV	1807-47703	GREEN	L	6/4	165.445	F	912	0-25	352	1126	093
06 NOV	1807-47704	GREEN	L	6/5	165.815	F	1002	0-25	365	1128	092
06 NOV	1807-47705	GREEN	L	6/6	NA[a]	F	957	0-25	357	1104	091
06 NOV	1807-47706	GREEN	L	6/7	165.645[b]	F	1035	0-25	350	1054	092
20 NOV	2206-22894	BLUE	L	A/H	165.545	M	595	0-25	308	968	079
25 NOV	1807-47766	GREEN	L	6/8	165.625	F	870	0-25	351	NA	093
03 DEC	2206-22895	BLUE	L	A/K	165.665	M	591	0-25	310	950	077
09 DEC	816-70286[c]	BLACK	R	6/C	NA[a]	M	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]
19 DEC	2206-22897	BLUE	L	A/M	165.964	M	546	0-25	303	928	078
19 DEC	2206-22898	BLUE	L	A/P	NA[a]	M	611	0-25	314	950	078

[a] NA indicates no application or measurement on that respective falcon.
[b] Recovered mortality.
[c] Denotes previously banded individual.

Use of Nest Boxes by American Kestrels in Southwestern Idaho

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ANNUAL SUMMARY

*American kestrels (**Falco sparverius**) nested in 9 boxes along I-84, 9 boxes on the Kuna route, and 20 boxes on the Carpenter route in 1994. Occupancy rates along I-84 and near Kuna (37%) were similar to those in past years and higher than on the Carpenter route (30%). Nesting success rates (64%) were within the ranges recorded in past years, but Carpenter boxes had higher success rates (70%) than traditional boxes. Few individuals marked as breeding adults in 1993 returned to breed in the same box in 1994. Since our study began, we have encountered only 6 breeding kestrels (5 females and 1 male) that were originally marked as nestlings in the study area.*

OBJECTIVES

1. Determine kestrel occupancy rates and nesting success at boxes erected in southwestern Idaho.

2. Mark nestling and adult kestrels to assess site fidelity and natal dispersal.

INTRODUCTION

Monitoring of nest boxes along Interstate-84 and near Kuna, Idaho began in 1986 as a cooperative effort with the Idaho Department of Fish and Game and the Idaho Department of Transportation. The Raptor Research and Technical Assistance Center has had sole responsibility for monitoring the boxes since 1989. In 1993 we began to assess the fidelity of kestrels to boxes (Drysdale 1993). In 1994 RRTAC's investigations expanded to include approximately 70 boxes erected in the Boise/Kuna area by George Carpenter in 1992 as part of his graduate study. Work in 1994 was carried out cooperatively with another Boise State University graduate study (see Heath, this volume).

METHODS

We checked boxes in 3 separate study areas in southwestern Idaho: on trees within agricultural habitat in the vicinity of Kuna, Idaho (hereafter referred to as the Kuna route); on highway signs

along Interstate 84 between Simco Road and Caldwell (hereafter referred to as the I-84 route); and on 2 x 4 poles along fence lines in rural and suburban areas near Boise and Kuna, Idaho (hereafter referred to as the Carpenter route). We did not check boxes on abandoned power poles along the north rim of the Snake River Canyon (formerly known as the BOPA route). In 1994, 116 boxes were available to kestrels for nesting: 27 on the I-84 route, 22 on the Kuna route, and 67 on the Carpenter route.

We checked, cleaned, and added fresh shavings to all boxes in March. We re-visited all boxes in late April, late May, and early June to check for occupancy. We removed nests of European starlings (*Sturnus vulgaris*) in an effort to keep all boxes suitable for kestrel nesting. Occupied boxes (i.e., those with kestrel eggs or young) were re-visited from May through July as necessary to capture adults, band young, and ascertain nesting success. Investigators checked boxes while standing on a ladder. When checking boxes, investigators inserted a hole stuffer into the nest box entrance to trap any adult birds in the box. After young were 1 week old, we used a mist net with a live great horned owl (*Bubo virginianus*) to capture adults we had been unable to catch in boxes during incubation (Steenhof et al. 1994). We weighed adults and young with a 300-g Pesola balance. We considered nests to be successful if young could be sexed (75% feathered: approximately 22 days; Griggs and Steenhof 1983).

RESULTS

Occupancy

Kestrels nested in 38 of 116 available boxes (33%) in 1994. Occupancy rates were highest on the Kuna route, where kestrels nested in 9 of 22 boxes (41%), intermediate on the I-84 route (9 of 27 boxes occupied; 33%), and lowest on the Carpenter route (20 of 67 boxes occupied; 30%). The 1994 box occupancy rates on the Kuna and I-84 routes were near mean values observed during the 9-year study (Table 1).

Although the number of boxes used on I-84 in 1994 was the same as in 1993, only 5 of the 9 boxes used in 1994 had been used in 1993. Three had been used in 1992, and 1 was last used in 1991. Similarly, only 5 of 9 boxes used by kestrels in 1994 on the Kuna route had been used in 1993. Two were last used in 1992, and 2 were last used in 1991. On the Carpenter route, 13 of 20 boxes used in 1994 had been used in 1993. Four were used for the first time, and 3 were last used in 1992.

Table 1. Occupancy rates of kestrel boxes on the Kuna and I-84 routes, 1986-94. Number of available boxes in parentheses.

Year	I-84		Kuna		Overall	
1986	24%	(17)	18%	(17)	21%	(34)
1987	41%	(32)	39%	(31)	40%	(63)
1988	30%	(30)	40%	(30)	35%	(60)
1989	28%	(29)	27%	(30)	27%	(59)
1990	36%	(28)	38%	(26)	37%	(54)
1991	36%	(28)	58%	(24)	46%	(52)
1992	36%	(28)	59%	(22)	46%	(50)
1993	33%	(27)	32%	(22)	33%	(49)
1994	33%	(27)	41%	(22)	37%	(49)
$\bar{x}$	33%		39%		36%	

Reproduction

Overall nesting success of 38 kestrel pairs in 1994 was 66%. Kestrels on the Carpenter route had the highest success rates (70%), and kestrels on the Kuna route had the lowest (56%). Success rates on the I-84 route were intermediate (67%). Nesting success rates on the Kuna and I-84 routes were within the ranges observed in previous years (Table 2).

Clutch size averaged 5 at 32 boxes where we counted eggs. Twenty-five pairs laid 5 eggs, 4 pairs laid 6 eggs, 2 pairs laid 4 eggs, and 1 pair laid 3 eggs. All eggs failed to hatch in 8 boxes, and nestlings died in ≥4 boxes. Five successful nests had ≥1 egg that failed to hatch. We observed a brood of 6 for the sixth consecutive year in 1994.

Site Fidelity

We banded 175 kestrels (69 adults, 99 nestlings, and 7 hand-reared birds) in or near boxes along the 3 routes in 1994. These totals include many kestrels captured in bal-chatri traps during the non-breeding season. We also recaptured 18 kestrels that had been banded in previous years. We captured 87% percent of all adult kestrels nesting in boxes in 1994 (76% of the males and 97% of the females).

Of the 37 marked females that bred in boxes in 1993, only 3 (8%) returned to breed in the same box in 1994. Eighteen of the boxes used by marked females in 1993 were occupied by new females in 1994, and 15 were not occupied at all in 1994. We were unable to catch the female at 1 box, but the female marked there in 1993 may have re-used the box. The 1994 nesting attempt at that box failed early, and we encountered the 1993 female late in the nesting season in a new box about 2 km from her 1993 box. We suspect that she returned to her 1993 box in 1994, failed early, and moved elsewhere to re-nest.

Of 22 marked males that bred in boxes in 1993, only 2 (9%) returned to breed in the same box in 1994. Twelve boxes used by marked males in 1993 were not re-occupied in 1994, and 8 were used by new males. Four other males marked in 1993 moved to different boxes within the study area in 1994. Distances between boxes used in 1993 and 1994 ranged from 0.4 to 4.6 km and averaged 1.8 km. At least 3 of the 4 males who changed boxes paired with new mates. Three of the 4 boxes they left were unoccupied in 1994; a fourth was occupied by a new male.

Table 2. Percent of kestrel nests successful on the Kuna and I-84 routes, 1986-94. Sample sizes in parentheses.

Year	I-84		Kuna		Overall	
1986	100%	(4)	0%	(3)	57%	(7)
1987	54%	(13)	55%	(11)	54%	(24)
1988	44%	(9)	50%	(12)	48%	(21)
1989	25%	(8)	75%	(8)	50%	(16)
1990	80%	(10)	89%	(9)	84%	(19)
1991	70%	(10)	64%	(14)	67%	(24)
1992	60%	(10)	77%	(13)	70%	(23)
1993	78%	(9)	86%	(7)	81%	(16)
1994	67%	(9)	56%	(9)	61%	(18)
$\bar{x}$	64%		61%		64%	

All 3 females that returned to the same boxes had bred successfully in 1993. One was paired with a new male, and the other 2 mated with their 1993 mates. Both of the males that returned to boxes in 1994 mated with their 1993 mates, and both had successfully raised young with these mates in 1993. Although all kestrels that returned to their 1993 boxes in 1994 had successfully raised young in 1993, success in 1993 did not seem to affect whether a particular box would be occupied by new kestrels in 1994. Forty-two percent of boxes with marked females that were unsuccessful in 1993 were occupied by kestrel pairs in 1994 (all of these with new females), and 60% of boxes with successful marked females were occupied (some by new and some by returning kestrels). Of 2 boxes where marked males failed in 1993, 1 was unoccupied and 1 was used by a different male. Boxes where marked males had been successful in 1993 had a similar, but slightly lower occupancy rate of 45%. None of the differences in occupancy rates were significant (P's > 0.05).

During the entire study period, we have encountered only 6 breeding kestrels that were originally marked as nestlings in our study area (Table 3). This amounts to approximately 1 percent of all birds we marked as nestlings through the end of 1993. One male was found breeding in his first year, and females were found in both their first and second year. Females moved 8.3-10.8 km ($\bar{x}$ = 10 km; SD = 1.03 km) from their natal boxes to their breeding boxes. The male moved 7.6 km. The fact that we have more females in the sample probably results from the fact that it was easier for us to catch females--not because they were more likely than males to return.

PLANS FOR NEXT YEAR

Monitoring of occupancy, reproduction, and site fidelity will continue in 1995. We will continue attempts to capture and identify all breeding adults, and we will expand our effort to capture and mark kestrels during the nonbreeding season.

ACKNOWLEDGMENTS

This study could not have been completed without the assistance of Michelle Drysdale, Erica Schutter, Julie Heath, and George Carpenter. Carolyn Fritschle and Barbara Stuart also assisted with field work. We are especially indebted to the landowners in the Kuna area who graciously allowed us to set up and check boxes on their property. The National Geographic Society donated a ladder to the study.

Table 3. Natal dispersal distances of kestrels banded as nestlings in southwestern Idaho, 1992-94.

Band number	Sex	Year marked	Year encountered	Age at breeding (Years)	Distance moved (km)
1493-16244	F	92	93	1	10.7
1493-15961	F	92	93	1	10.4
2003-20929	F	93	94	1	9.7
2003-16103	F	90	92	2	8.3
1493-15957	F	92	94	2	10.8
2003-20897	M	93	94	1	7.6

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Post-fledging Movements of American Kestrels

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ANNUAL SUMMARY

*American kestrel (**Falco sparverius**) post-fledging dispersal may be initiated by environmental or innate proximate factors. Some environmental factors are social interactions, parental aggression, and prey abundance. I studied the effects of environmental conditions, in particular prey abundance, on age of post-fledging dispersal. I also attempted to relate dispersal timing with body mass. Preliminary results indicate kestrel dispersal is not directly affected by environmental conditions or body mass.*

INTRODUCTION

In raptors, the post-fledging period is critical for development of hunting and social skills (Weathers and Sullivan 1989; Bustamante 1993). The quality of the environment, such as food abundance, determines (to some extent) the successful development of these skills. If resources are limited, individuals may increase their post-fledging movement to avoid starvation, leaving their natal area earlier than other individuals (Pärt 1990). Alternatively, if resources are limited, then individuals may stay in the natal area to continue foraging in a familiar territory until they are able to meet their metabolic needs, at which point they may disperse (Nilsson and Smith 1985). This variation in dispersal strategy may indicate that both environmental factors and innate predisposition can affect movement.

Proximate dispersal factors may be innate (i.e., birds have a genetic predisposition to leave their natal area) or environmental (i.e., birds move away from their natal area in response to environmental fluctuations) (Howard 1960). Some studies that examined post-fledging movement in raptors support the idea that dispersal is driven by changes in environmental conditions (*Strix nebulosa;* Bull et al. 1988). Other studies show that endogenous forces may be among the proximate factors for dispersal (*Circus cyaneus*; Beske 1982; *Otus asio*; Ritchison et al. 1992). A likely explanation may be that a combination of environmental conditions and innate predisposition influence dispersal timing and distance.

An ability to respond to environmental conditions may depend on physiological condition. For example, juvenile Spanish imperial eagles (*Aquila adalberti*) in better physical condition, determined by uric acid levels in the blood, dispersed earlier

than birds in poor condition (Ferrer 1992). Birds in poorer physical condition may remain in the natal area to continue gaining fat and practicing to hunt.

Here I report preliminary data on proximate factors of American kestrel post-fledging movement in southwestern Idaho. I focus on prey abundance and body mass in relation to dispersal age. I will use the terms dispersal and post-fledging movement to describe movements from the natal area. This contrasts with natal dispersal meaning movement from the natal area to a potential breeding site (Greenwood 1980).

METHODS

I conducted a natural experiment in southwestern Idaho. Karen Steenhof, Michelle Drysdale, and I began checking boxes for occupancy in mid-March. If we suspected a box was occupied we returned to band the adults. I focused my study on 7 broods. When the chicks reached 25 days of age I returned to band fledglings with U.S. Fish and Wildlife bands, collect blood, measure mass and wing chord, and mark the birds. To minimize stress effects on hormone titer, blood was drawn within 7 min. of capture. I collected blood from a brachial vein using a needle and carroway tubes.

I marked 1 bird per brood with a radio transmitter and its siblings with color leg jesses. I used Wildlife Material radios fitted backpack style. Backpacks consisted of Teflon ribbon passed through a leather breast patch fastened with cotton thread and super-glue. Traditional falconer style leg jesses were made of colored herculite leg jesses. Jesses were 1.5 cm wide by 6-7 cm long, leaving a trailing tab of 2-3 cm (Platt 1980; Varland et al. 1993).

I attempted to locate each radio- marked bird daily. I plotted locations on a 7.5-min. U.S.G.S. map and recorded UTM coordinates. I analyzed data points on the Ranges IV computer program (Kenward 1990). I also recorded the presence of siblings and parents. Siblings were identified by their color markers. Parents were identified by behavior such as defense and feeding of young. When I could not locate a radio-marked bird in its natal area I drove a circle 2-3 km around its natal area. If I could not locate the bird I considered the bird dispersed. I continued to visually check natal areas until there were no remaining siblings.

To assess body condition of post-fledging birds I attempted to capture birds using a carrion-baited noose trap. This trap has proven to be more effective than a bal-chatri for catching juvenile kestrels (Wegner 1981). The trap consists of 2 wires with 10 monofilament nooses. The wires were placed over a dead mouse nailed to a fencepost. I placed the traps on fence-posts that I routinely witnessed birds using for a hunting or feeding perch.

To get a relative estimate of prey abundance I measured vole burrow and grasshopper densities. To measure vole burrows I choose 3 50-m line transects within the brood's natal area. Transects usually followed fences or power lines that kestrels used for hunting. Every 5-m I counted holes in a 1-m^2 area. I determined grasshopper presence by walking 3 50-m transects, choose in a similar manner and counting the number of grasshoppers jumping to the side.

RESULTS AND DISCUSSION

Studies on avian dispersal show environmental factors can influence dispersal. Some of these factors are social interactions, parental aggression, and prey abundance. For example, northern goshawk (*Accipiter gentilis*) dispersal depends on food availability and social interactions. Subordinate males dispersed in response to aggression from dominant females, probably because they were unable to fend for themselves in food-stressed conditions (Kenward et al. 1993). In my study, related juvenile American kestrels dispersed within 1 day of each other. This suggests social status may not be a proximate mechanism for dispersal. Instead, the juvenile period may depend on social interactions among young kestrels. I observed social hunting in all focal broods. Juvenile kestrels perched along fence lines and imitated an adult or other juvenile kestrels hopping to the ground or making short bursts of flight away from the fence. At 2 sites I witnessed unmarked juvenile kestrels from other broods hunting near or with focal broods. These observations agree with

Varland's study on the post-fledging period of kestrels in Iowa (Varland and Loughin 1992).

I also observed parental feeding in all broods during the first week of post-fledging. After the second week parent detectability decreased probably because of decreased parental feeding (Varland et al. 1993). I never observed parental aggression, and this indicates parental aggression is not a proximate factor in kestrel dispersal (Wyllie 1985).

Past dispersal studies show that food availability can affect dispersal timing and distance (Pärt 1990). Preliminary results indicate kestrel dispersal age does not correlate with prey abundance ($r^2 = 0.49$; $P = 0.2541$; Table 1). However, other factors such as hunting ability may limit food availability. Perhaps the best indicator of food intake is body mass. To evaluate physical condition post-fledging birds must be trapped in their natal areas before they disperse. This year I captured 2 post-fledging kestrels. Both birds were in approximately the same physical condition, but dispersed at different ages (Table 2). This indicates food intake or body condition may not be a proximate factor of kestrel dispersal. However, this is a small sample size. Young birds were very difficult to trap with noose traps because they tended not to stay on the trap long enough to be caught. Next year I plan to use a portable bow-net as well as noose traps to increase my capture success.

Blood chemistries and hormone titers remain to be analyzed. Perhaps these variables will lend insight to innate or physiological mechanisms of post-fledging dispersal.

Post-fledging mortality was greatest during the first week after fledging. This agrees with Varland's observations on an Iowa population (Varland et al. 1993). Of the 5 birds I found dead, 1 was electrocuted, and 4 collided with automobiles. I also found 2 unbanded post-fledging kestrels that had been hit by cars. Nest boxes are in close proximity to roads and during their first week after fledging kestrels are not proficient flyers. This combination probably leads to the high incidence of collision.

Table 1. Kestrel post-fledging activity and prey abundance.

Box	Age Fledged	Age Dispersed	Vole Burrow/m^2	Grasshopper/m^2
Carpenter 46	28 days	47 days	1.74	0.03
Kuna 14	27 days	49 days	0.15	0.37
Kuna 103	29 days	47 days	0.74	0.14
Carpenter 42	31 days	50 days	1.48	0.13
Carpenter 23	26 days	40 days	0.55	0.21
Kuna 111	32 days	54 days	0.04	0.42
Carpenter 29	29 days	47 days	1.11	0.09

Table 2. Post-fledging kestrel body measurements and activity.

Box	Band	Sex	Weight	Wing Chord	Age Dispersed
Kuna 103	200320849	m	109 g	170 mm	47 days
Carpenter 23	200320883	m	106 g	176 mm	40 days

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Nest Box Use in the Snake River Birds of Prey National Conservation Area

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ANNUAL SUMMARY

*Western screech-owls (**Otus kennicotti**) and American kestrels (**Falco sparverius**) used 28 of 45 available sites in 1994. Western screech -owls bred at 8 sites and American Kestrels at 1 site. All western screech-owl sites were used by Boise State University investigators studying dispersal of these owls.*

OBJECTIVES

To determine patterns of nest box use, fidelity to site and mate, reproductive success, food habits, and annual body mass.

METHODS

Ninety boxes were available at 45 sites during 1994. All boxes were visited October through May. Ethan Ellsworth (see report this publication) continued site visits until the young dispersed, died, or disappeared. Adult size screech-owls were weighed with a 300 g Pesola spring scale and the flattened wing-cord was measured to the nearest millimeter. Owls were sexed by the presence or absence of a brood patch during the breeding season. Unbanded owls were banded when encountered and age-classed by the color of the underwing. Thirty-four of 35 nestling owls were sexed using a molecular probing technique on blood samples collected by Dr. James Belthoff of Boise State University. All boxes are cleaned out each fall and prey remains are collected and stored. Boxes are repaired as needed through the year.

RESULTS

Boxes at 28 of 41 sites were used by roosting or breeding screech-owls. Eight sites were used by

breeding screech-owls. Eighteen adult size and 35 nestling screech-owls were banded. Six of the banded nestling owls were taken into captivity by Belthoff (see this publication). We measured body mass of adult sized owls on 51 occasions. Twelve female owls' body mass ranged from 196-269 g, 8 males' body mass ranged from 161-198 g, and the body mass of owls of unknown sex ranged from 161-238 g. There is no evidence of breeding owls changing site or mate. Wing chord measurements varied so much from visit to visit and among researchers that they cannot be analyzed, and this measurement will be dropped from this study.

American kestrels bred at 1 site (River Road) this year.

Ellsworth and Belthoff used all screech-owl breeding sites for their research. Ellsworth will discuss fledging success of the owls in this publication.

PLANS FOR 1995

The cooperative study with Boise State University will continue. The objectives for this study will remain the same as 1994.

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Locomotor Activity Levels in Juvenile Western Screech-Owls and the Internal Component of Natal Dispersal

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ANNUAL SUMMARY

*This study examined the internal component of dispersal in juvenile western screech-owls (**Otus kennicottii**). We monitored locomotor activity levels in young, captive owls in relation to the timing of dispersal movements made by free-living individuals. We predicted that if dispersal has an internal component, it might exhibit itself in increased locomotor activity near the time of dispersal, similar to increasing locomotor activity shown by birds preparing to migrate. Activity levels of captive owls increased in the weeks leading up to dispersal, peaked near the time when free-living birds were making dispersal movements, and declined thereafter. These results are consistent with those from earlier studies on eastern screech-owls (**Otus asio**) and support the notion that there is a detectable internal component to the dispersal behavior of young birds. Our future work will strive to understand the physiological mechanisms associated with increased activity levels and other proximate factors affecting natal dispersal in birds.*

INTRODUCTION

Important factors influencing the initiation of dispersal may be either *external* (environmental) or *internal* (endogenous) (Howard 1960). External factors include parental aggression toward young (Wiggett and Boag 1993), aggression of young toward each other (Holleback 1974, Gauthreaux 1978, De Laet 1985, Strickland 1991), and perhaps declines in food availability (Kenward et al. 1993). Despite evidence that external factors drive natal dispersal in some species, they appear less important in others. For instance, independent young marsh tits, *Parus palustris*, disperse from natal territories despite experimental removal of their parents and unlimited access to food

(Nilsson 1990). This indicates that neither diminishing food supply nor parental aggression causes young to disperse and suggests that dispersal in some species has an internal or endogenous component.

To examine whether dispersal in birds is related to endogenous events, Ritchison et al. (1992) monitored activity levels of captive, juvenile eastern screech-owls throughout their normal postfledging period. There is no evidence that either parental aggression or aggression among young causes screech-owls to disperse, and circumstantial evidence suggests that such aggression is rare (Belthoff and Ritchison 1989, 1990, Belthoff et al. 1993). Thus, it is likely that dispersal in this species has an internal component. Ritchison et al. (1992) speculated that this internal component may manifest itself in increased locomotor activity near the time of dispersal (cf. Holekamp 1986) and that young owls may exhibit "dispersal restlessness" when maintained in captivity. Ritchison et al. (1992) observed that activity levels of young, captive owls increased in the weeks leading to dispersal, remained high through the period of dispersal, and declined thereafter. Moreover, data from free-living, radio-tagged birds showed a similar trend. These results constitute the first evidence for a relationship between activity levels and timing of natal dispersal in birds, and they suggest that natal dispersal in eastern screech-owls is influenced by intrinsic factors.

Because comparative information was unavailable to Ritchison et al. (1992), the general importance of this relationship between dispersal and locomotor activity levels among avian species could not be assessed. In the present study, we examined locomotor activity levels and dispersal in a related species of bird, the western screech-owl. Our data concur with Ritchison et al. (1992) and indicate that activity levels in western screech-owls are high in the weeks leading to dispersal, peak near the time when free-living individuals are dispersing, and decline thereafter. Thus, it is likely that dispersal in western screech-owls also has an intrinsic component. Our study represents the first step in assessing the generality of this relationship in birds.

METHODS

Using birds that had been isolated from extrinsic factors (population density, social influences, and fluctuations in food availability) since early in life, our objective was to determine if increased locomotor activity, triggered by endogenous factors, occurs in young western screech-owls near the time of dispersal. Between 15-23 May 1994, we removed 6 nestling western screech-owls (females: owls 125 and 134; males: owls 101, 124, 129, 133) from 4 nest boxes along the Snake River in Elmore and Owyhee Counties, located approximately 60 km southeast of Boise, Idaho. At the time of collection, all owls appeared to be about the same age based on development (about 24 days old or about 1 week from fledging). In captivity, owls were kept in wire-mesh cages measuring approximately 0.5 m high x 0.5 m deep x 1.0 m wide, which were placed in individual sound-attenuated isolation chambers. Once in chambers, owls could not interact visually or vocally. Owls were provided laboratory mice, day-old chickens, and water, and natural photoperiods were maintained. Blood samples were collected from the brachial vein once per week to determine circulating levels of hormones; results of hormone analyses will be reported elsewhere following completion of radioimmunoassays.

Fledging dates for captive owls were estimated based on fledging dates of free-living nest mates. We monitored activity levels for 16 weeks post-fledging (26 May-23 September 1994), by which time the initial dispersal movements of 19 young, radio-tagged screech-owls within the study area concluded (Ellsworth and Belthoff unpubl. data). We used Micronta Mini Jog-Mate pedometers (Cat. No. 63-667, Radio Shack, Fort Worth, Texas) to quantify activity in captive owls. These digital pedometers register steps or "hops" (i.e., individual up-and-down movements) rather than distance and, therefore, provide accurate information concerning number of movements or locomotor activity (Ritchison et al. 1992). We attached pedometers to owls back-pack style with woven nylon cord. Complete packages, i.e., pedometers plus nylon cord, weighed 9g (between 4.1 and 5.6% of each individual's body weight). We read each owl's pedometer daily at 1100 hours between May and August, and around 1600 hours thereafter. Following rehabilitation, captive owls were released.

Western screech-owls in southwestern Idaho initiate natal dispersal movements between late June and early August, an average of 58 ± 2.6 (SE) days after fledging (N = 18, range = 47 - 81; Ellsworth and Belthoff, unpubl. data). For many, these initial dispersal movements end less than 1 week later. Thus, if not taken into captivity, young screech-owls in the present study would probably have initiated dispersal sometime during weeks 7 - 10.

RESULTS

We examined differences in locomotor activity levels over time by pooling activity data into 7-day periods (weeks postfledging). For all 6 owls combined, activity levels increased through the first 7 weeks postfledging, and then declined over the next 9 weeks (Fig. 1). Although number of hops varied among individual owls, the average activity levels of 5 of the 6 owls were similar to the overall pattern; only owl 133 differed markedly from the rest (Fig. 2). Peaks in activity occurred in week 8 for owls 124 and 125, week 7 for owl 134, week 6 for owl 129, and week 5 for owls 101 and 133.

Captive western screech-owls clearly increased locomotor activity in the weeks leading to dispersal and exhibited high activity during the time period when dispersal normally occurs in free-living owls. Activity levels typically declined steadily following this period. Relatively high activity levels before and during the predicted dispersal period suggests that natal dispersal in western screech-owls also has an intrinsic or endogenous component. This pattern is similar to the only other species of bird examined to date, i.e., eastern screech-owls. Similar patterns of locomotor activity in relation to dispersal also occur in Belding's ground squirrels (*Spermophilus beldingi*; Holekamp 1986).

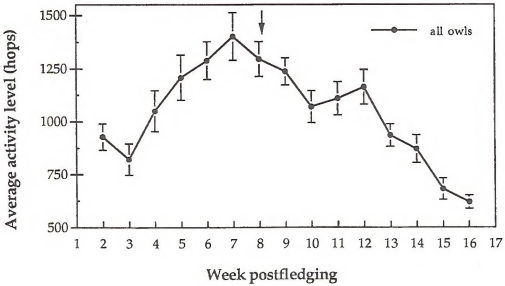

Fig. 1. Average (± SE) weekly locomotor activity levels of captive, juvenile western screech-owls (N = 6) during the postfledging period. The arrow represents the mean date of initiation of dispersal in free-living western screech-owls (N = 18) in southwestern Idaho.

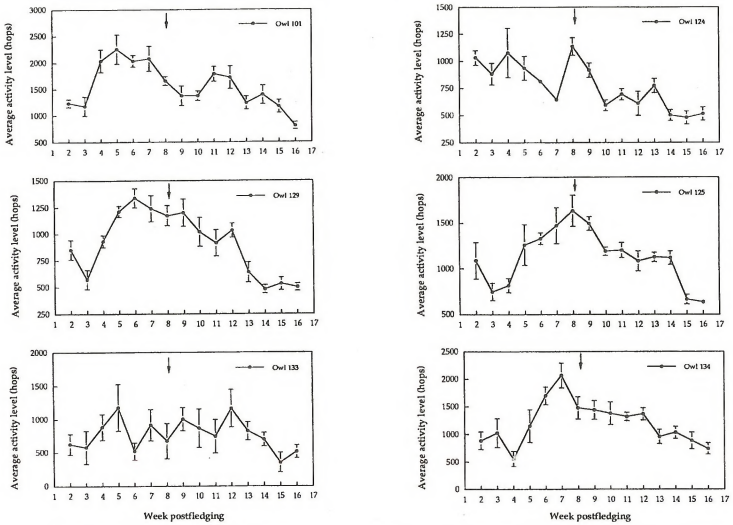

Fig. 2. Average (± SE) weekly locomotor activity levels for 6 captive, juvenile western screech-owls during the postfledging period. Arrows represent the mean date of initiation of dispersal in free-living western screech-owls ($N = 18$) in southwestern Idaho.

Our results constitute the first step in understanding the generality of the relationship between locomotor activity levels and dispersal in birds, and they corroborate those of Ritchison et al. (1992) using a different model species, i.e., western screech-owls. Our current work focuses on understanding the physiological and hormonal factors related to activity levels and dispersal in both captive and free-living birds.

PLANS FOR 1995

This study will continue in 1995 and include field and laboratory experiments to understand the relationship between body condition, hormones, and locomotor activity levels in young owls.

ACKNOWLEDGMENTS

We thank Linda Belthoff, John Doremus, Ethan and Mia Ellsworth, Jennifer Emerson, Julie Heath, Andy King, and Jason Sutter for assistance in the laboratory and field. Funding for this study was provided by Idaho Board of Education Specific Research Grant S95-042 and by the Biology Department and Raptor Research Center at Boise State University. We thank the Boise District of the U.S. Bureau of Land Management, the Snake River Birds of Prey National Conservation Area, and particularly J. Doremus for facilitating our field work on owls. We collected young owls under U.S. Fish and Wildlife Service Permit #PRT 785053 and a State of Idaho, Department of Fish and Game Scientific Collecting Permit #SCP 930810.

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Post-fledging Movements and Dispersal Timing of Western Screech-owls

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ANNUAL SUMMARY

*We studied the post-fledging behavior and dispersal of juveniles in 8 families of western screech-owls (**Otus kennicottii**). Within 4 focal broods we also examined the effects of behavioral dominance on the timing and distance of dispersal movements made by young owls. To assess dominance status within focal broods, we video-taped interactions among owls throughout the nestling period using video-cameras placed atop nest boxes. Prior to fledging, we equipped 25 juveniles and 7 adults with radio-transmitters so that we could follow their movements. We located all radio-tagged owls daily during the post-fledging period up to the time when young dispersed from natal areas. We noted roosting behavior and movements during this period, and recorded the date when juvenile owls began dispersing from natal areas. Following the initiation of dispersal, we performed 3 aerial and numerous foot searches to locate dispersing juveniles. We recorded the distance of movements made by dispersing juveniles and the occurrence of subsequent movements throughout the autumn and winter.*

OBJECTIVES

Our objectives in the present study are to:

1. Determine dominance relationships among siblings in broods of western screech-owls;
2. Describe the post-fledging behavior of western screech-owls; and
3. Determine the timing and distance of dispersal movements in juvenile western screech-owls in relation to dominance status. Our results will allow us to examine hypotheses concerning the role of sibling aggression on the dispersal movements of birds.

INTRODUCTION

Natal dispersal occurs in virtually all birds and mammals prior to first reproduction, and the proximate factors responsible for natal dispersal movements have been the subject of conjecture for more than 3 decades. Howard (1960) suggested that dispersal may be of 2 types: (1) innate dispersal, in which animals are predisposed at birth to disperse beyond the confines of their parental home range, and (2) environmental dispersal, in which animals move away from their birth place in response to factors such as the absence of, or competition for, suitable resources.

Our study focused on the role of sibling aggression (social dominance) as a proximate environmental mechanism leading to dispersal in young western screech-owls. In the field we assessed how sibling aggression between western screech-owl chicks influenced natal dispersal patterns. Our research addressed the following questions: Do dominant birds evict subordinates from natal areas? Does dominance status affect the timing of dispersal in young? Are dominant birds gaining quality territories at the expense of subordinates and causing subordinates to disperse farther in search of suitable habitats? Does sex-biased dispersal occur independent of dominance? In this paper we review the field methods we employed to address these questions during our initial season, and we present preliminary results on the timing of dispersal movements in juvenile western screech-owls.

METHODS

We studied western screech-owls nesting in nest boxes on 46 sites in the Snake River Birds of Prey National Conservation Area and adjacent public land along the Snake River near Grand View, Idaho. To examine post-fledging movements and dispersal, we equipped individuals in 8 families (referred to as Bruneau Boat Launch, Bruneau Marsh, Cabin, Cellar Hole, Delta East, Rabbit Springs, Strike Camp, and Ted Trueblood WMA families) with radio-transmitters. However, we chose 4 focal broods (Bruneau Marsh, Cabin, Delta East, and Rabbit Springs families) to investigate the relationship between dominance status and dispersal patterns. To examine the relationship between dominance status and the timing and distance of dispersal movements we: (1) video-taped the interactions of nestlings within the 4 focal broods; (2) radio-tracked juveniles and adults during the post-fledging period; and (3) located dispersing juveniles from airplanes or through foot searches of the study area.

To video-tape nestling interactions, we removed original nest box covers from nest boxes of focal broods, and replaced them with camera-adapted boxes when the chicks were approximately 1 week old. We waited until the chicks were >1 week of age to ensure that they could thermoregulate properly if adult females refused to reenter camera-equipped nest boxes to brood young. In fact, all focal females returned to brood young following the placement of video cameras. We video-taped each focal brood every other night until the chicks fledged and reviewed the video-tapes to establish a hierarchical ranking of nestlings. Based on the number of wins and losses in aggressive interactions, we ranked individuals within broods from most dominant to least dominant (subordinate). We do not report on the results of brood interactions in this paper.

Juvenile owls were captured from nest boxes approximately 1 week before fledging (i.e., leaving the nest box). Twenty-five of 26 juvenile western screech-owls from 8 families were fitted with radio transmitters (5g; Wildlife Materials Inc., Carbondale, Illinois, backpack style with woven nylon cord; Smith and Gilbert 1981). We failed to put a transmitter on 1 juvenile that fledged early at the Delta East nest. In addition, 2 young and the adult female at the Delta East nest had their transmitters fail, and these birds were not re-located throughout the post-fledging period. A nearby great horned owl (*Bubo virginianus*) preyed upon one of the Delta East chicks with a working transmitter and may also account for the other Delta East disappearances. We also attached transmitters to 7 of the 8 adults in the 4 focal broods (4 females and 3 males). After the chicks fledged, we located family members from all 8 broods daily until the juveniles dispersed from natal home ranges. For each sighting we recorded the owl's roost height, roost type (tangle, trunk, or limb), tree species, tree height, diameter of roost tree at breast height (DBH), distance from previous roost, distance from

nest, distance from adults, and distance between juveniles within a brood.

After dispersal of young, we ended our daily monitoring and made 3 airplane flights in search of dispersing juveniles. Dispersal movements were typically characterized by an abrupt, unambiguous, long-distance movement out of the natal home range without subsequent return. We noted the dispersal date for 18 of 26 juveniles. We also recorded dispersal distances for 16 of 18 juveniles that dispersed, and we are continuing to monitor these 16 juveniles to assess subsequent movements and to analyze winter site characteristics.

RESULTS AND DISCUSSION

The mean fledging date for 26 juvenile western screech-owls was 16 May (range: 8 May - 29 May). Siblings from the same nest did not always fledge on the same night; in fact, the first Cabin juvenile to leave the box left 7 days before the last. Juvenile screech owls that escaped predation and had no transmitter problems remained in natal areas for an average of 58.2 days after fledging (range: 44-81 days; n = 18). Initial dispersal movements by juveniles occurred between 30 June and 2 August (mean = 12 July; n=18) and varied among siblings and families (Table 1). For example, 26 days elapsed between dispersal of the first and last juveniles in the Cabin family (Table 1). Three juveniles died before dispersal (1 great horned owl predation event at Delta East, and unknown cause of death at Cellar Hole and Strike Camp), 4 birds apparently had their transmitters fail (all from Delta East), and 2 individuals remained in their respective natal areas before dispersing sometime in the fall, after daily monitoring had concluded (owls 136 and 399 from Strike Camp and Bruneau Boat Launch, respectively).

Preliminary results show that the timing of disperal in western screech-owls is variable within broods. Future data analyses will determine whether or not this variation can be attributed to social interactions between brood members, sex, or size.

PLANS FOR NEXT YEAR

Objectives of this study will remain the same in 1995. We plan to continue both video-taping at nest boxes and radio-tracking young and adults during the pre-dispersal period and dispersal periods to understand the post-fledging behavior of young western screech-owls.

ACKNOWLEDGMENTS

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Table 1. Timing of the initiation of natal dispersal movements in 26 juvenile western screech-owls.

Family	Owl Number	Sex	Fledging Date	Dispersal Date	Days Post-fledging
Cabin	745-64-103	male	14 May	22 July	69
	745-64-104	female	13 May	2 Aug	81
	745-64-105	female	14 May	7 July	54
	745-64-106	female	12 May	26 July	75
	745-64-107	female	8 May	28 July	81
Bruneau Marsh	745-64-108	male	16 May	14 July	59
	745-64-109	female	17 May	10 July	54
	745-64-110	male	15 May	2 July	48
	745-64-111	male	16 May	2 July	47
Rabbit Springs	745-64-112	female	13 May	30 June	48
	745-64-113	female	16 May	4 July	49
Delta East	745-64-115	female	12 May	6 July	55
	745-64-116	female	12 May	?	?
	745-64-117	female	13 May	?	?
	745-64-118	female	13 May	died 29 May [b]	
	745-64-119	?	11 May	?	?
Cellar Hole	745-64-123	female	16 May	died 11Aug - 1Sep[c]	
Ted Trueblood WMA	745-64-128	male	18 May	8 July	51
	745-64-130	male	18 May	15 July	58
	745-64-131	male	16 May	13 July	58
Bruneau Boat Launch	745-64-100	male	16 May	4 July	49
	745-64-120	male	14 May	7 July	54
	745-61-399	female	15 May	?	?
Strike Camp	745-64-132	male	29 May	died Aug 4[c]	
	745-64-135	male	24 May	17 July	
	745-64-136	female	29 May	?	
Mean[a]			16 May	12 July	58.2

[a] Does not include juveniles that died or are still in natal territory.
[b] Carcass and radio transmitter found in great horned owl nest.
[c] Carcass and radio transmitter found in unidentified mammalian burrow

Feeding Ecology of the Barn Owl in the Snake River Birds of Prey National Conservation Area

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ANNUAL SUMMARY

*Surveys of traditional barn owl (**Tyto alba**) nest/roost sites revealed evidence of roosting at 5 sites, but nesting at only 3 sites. Diet data revealed only minor changes in major prey compared to 1993, most notably the 7.4% decrease in voles and 5% increase in deer mice and 5.1% increase in kangaroo rats.*

OBJECTIVE

To determine food-niche parameters and food-niche variation among collection sites and among years for barn owls nesting in the Snake River Birds of Prey Area National Conservation Area (SRBOPNCA).

METHODS

Owl diet data originated from regurgitated pellets that I collected at cliff sites occupied by barn owls. Most sites were occupied barn owl nests. All collections were made on 30 April 1994. Prey in the pellets were identified and quantified by standard methods (Marti 1987). See Marti (1988) for treatment of data from earlier years.

RESULTS AND DISCUSSION

Pellet samples were collected at 3 sites in 1994. Collection locations and sample sizes are given in Table 1. The 1994 dietary sample is summarized in Table 2. Only minor changes occurred in dietary proportions compared to 1993; voles (*Microtus montanus*) declined by 7.4% in barn owl diets while deer mice (*Peromyscus* spp.) increased by 5% and kangaroo rats (*Dipodomys* spp.) increased by 5.1% over 1993. See Marti (1991) for diet trends beginning in 1978.

Evidence of owl use was found at 5 sites in 1994, but nesting was documented at only 3 (Jensen Cliff, Lower Lower Black Butte and Upper Lower Black Butte). See Marti (1990, 1991, 1992, 1993) for comparisons of the number of occupied sites and size of diet samples in other years.

Table 1. Collection sites for barn owl diet data and number of prey in collection samples from the SRBOPNCA, 1994.

Collection Site	Number of Prey in Samples
Jensen Cliff	179
Lower Lower Black Butte	98
Upper Lower Black Butte	270

Table 2. Total prey identified for the barn owl in the SRBOPNCA, 1994.

Prey species	Number	Percent number
MAMMALS		
Sorex vagrans	2	0.14
Sylvilagus nuttallii (neo.)	1	0.2
Mus musculus	53	9.7
Peromyscus spp.	64	11.7
Reithrodontomys megalotis	15	2.7
Microtus montanus	301	55.0
Perognathus parvus	24	4.4
Dipodomys ordii	69	12.6
Thomomys townsendii (juvenile)	12	2.2
BIRDS		
unidentified icterid	1	0.2
unidentified small bird	4	0.7
unidentified medium bird	1	0.2
Totals	547	100

PLANS FOR 1995

Two trips to the SRBOPNCA are planned for spring/summer 1995. The objectives for 1995 are to continue collecting food habits data for the analysis of long-term predation trends by barn owls and to monitor trends in breeding numbers of barn owls at the traditional study sites.

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Wintering and Nesting Site Use by Long-eared Owls in the Snake River Birds of Prey Area

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ANNUAL SUMMARY

*During 3-7 January 1994, I checked 19 possible winter roost sites and found a total of 9 long-eared owls (**Asio otus**) at 3 of the sites. I captured 7 owls from these 3 sites; 2 were recaptures. During the breeding season, I checked 17 nesting groves and found 11 nests at 6 groves. I banded 26 juveniles, 3 adult males, and 4 adult females; none of the adults were recaptures. Although I observed bands on 1 breeding female and male, at different nests, I was not able to capture them. Most likely, these banded birds were ones that I had banded at the same sites the previous winter.*

OBJECTIVE

1. To gather long term demographic data on nesting and wintering long-eared owls in the Snake River Birds of Prey Area (SRBOPA).

METHODS

In the winter, from 3-7 January 1994, I searched for long-eared owls in 19 groves where I have trapped owls in previous winters, as well as groves that appeared suitable (Table 1). I used a jet boat to travel to Nahas Marsh, Tom Draw, and Sinker Creek Mouth. I trapped, banded, and determined the age of owls as in previous years (Ulmschneider 1993).

In the breeding season, I visited the SRBOPA twice, from 30 April-1 May and 27-30 May, 1994. I searched 17 groves that have had long-eared owl nests in the past. I concentrated trapping efforts where I observed banded owls or where there were several nests in 1 grove. I trapped using mist nets that I had modified by dividing them into 4 tiers, instead of the 2 tiers they came with. This modification greatly improved my trapping success because owls almost never escaped once they had hit the net. Several times, I caught adults within less than 1 minute of setting up the great horned owl decoy. See Ulmschneider (1993) for a description of my trapping methods and discussion of the problems I had with 2-tiered nets.

Table 1. Sites with wintering long-eared owls during 3-7 January 1994 in the Snake River Birds of Prey Area, Idaho.[a]

Site	Date	# Seen	# Banded	# Recaptures
Strike Ditch	3 Jan 94	2	2	0
Nahas Marsh	5 Jan 94	5	1	2
Strike Dam Marsh	6 Jan 94	2	2	0

[a]Sites searched with no owls found were: Loveridge Bridge, the Fish and Game Management area east of Loveridge Bridge, Crane Falls Lake, Crane Falls Sturgeon, Bruneau Flat, Emigrant Trail, Strike Dam Road, Jack Springs, unnamed grove east of Jack Springs, Castle Creek Mouth North, Rabbit Springs, Tom Draw, Sinker Creek Mouth, Fossil Creek Mouth, No Name Creek Mouth, and Sinker Creek Butte.

RESULTS AND DISCUSSION

I found only 9 wintering long-eared owls, after checking 19 sites. This was the lowest number of wintering long-eared owls in the SRBOPA since I began monitoring in 1988. Five of the 9 owls were at Nahas Marsh, which has been the principal roost for the last several years. I caught 3 of these 5 owls; 2 were recaptures (Table 2). One was in its fifth year and had roosted in Tom Draw for 2 winters and then in Nahas Marsh for 2 winters. The other was at least in its fifth year and had roosted in Fossil Creek Mouth, Tom Draw, and Nahas Marsh in successive winters. Both are probably males, judging by weights.

At the other 2 wintering sites, Strike Ditch and Strike Dam Marsh, I caught and banded all 4 owls. In the breeding season, I was able to see that the female at Strike Ditch was banded, but the male was not. At Strike Dam Marsh, I could see that the male was banded, but the female (which I captured) was not. It is likely that both of these banded birds were ones I had banded during the winter at these sites.

During the breeding season, I searched 17 sites, and found a total of 11 nests at 6 areas (Table 3). Many traditional sites had no nests, but Castle Creek Mouth North and Sinker Creek Butte each had 3 nests. I suspect the nests were clumped where there were local concentrations of prey, and that in most other areas prey abundance was low.

At Castle Creek Mouth North, there were nests at the central circle grove (CCMN I) and in both the north (CCMN III) and south (CCMN V) tree stringers. This was the first use of the north and south stringers by long-eared owls since I started my study, although Jeff Marks found nests here in 1980-81 (data on file at the Raptor Research and Technical Assistance Center, BLM). I almost missed these nests because I had stopped searching those parts of Castle Creek Mouth North. I only found them by hearing food begging calls on my second visit. These nest locations demonstrated that habitat use patterns do not necessarily continue year after year.

PLANS FOR NEXT YEAR

I plan to continue monitoring, trapping, and banding long-eared owls each winter and nesting season. Priority sites will be Tom Draw, Nahas Marsh, Fossil Creek Mouth, No Name Mouth, Castle Creek Mouth North, Crane Falls Sturgeon, Strike Ditch, Strike Dam Road, and Strike Dam Marsh.

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Table 2. Recaptured long-eared owls from January 1988-June 1994 in the SRBOPA. Captures from January to May 1994 are in italic type.

Location Banded	Band Number	Sex	Dates Captured (Wt. in Grams)
Castle Ck Mouth N I	816-44041	?	Apr 87 (juv); Jan 91 (281)
Tom Draw	896-36733	M	Jan 88 (271); May 89 (231); Dec 90 (245); May 91 (228) Feb 93 (255)
Tom Draw	896-36734	?	Jan 88 (272); Jan 89 (248)
Tom Draw	896-36735	M	Jan 88 (276); Jan 89 (252); May 90 (240)
Tom Draw I	816-74512	?	May 88 (268); Jan 89 (252)
Tom Draw	816-74592	?	Dec 89 (248); Dec 90 (268)
Tom Draw	816-74599	?	Dec 89 (249); Dec 90 (282)
Tom Draw	816-74909	?	Dec 90 (249); Feb 91 (250)
Tom Draw	816-74595	?	Dec 89 (241); Jan 92 (265); Jan 93 (277) *and Jan 94 (266) - at Nahas Marsh;*
Castle Ck Mouth N	816-74922	F	Jan 91 (>288); May 92 (292)
Fossil Creek Mouth	816-74927	?	Feb 91 (277); Jan 92 (250) - at Tom Draw; *Jan 94 (247) - at Nahas Marsh*
Fossil Creek Mouth	816-74929	M	Feb 91 (272); May 91 (219) and Jan 93 (266) - at Castle Mouth N
Fossil Creek Mouth	816-74931	?	Feb 91 (269); Feb 92 (250)
Castle Ck Mouth N	816-74979	?	Jan 92 (223); Feb 92 (--) - at No Name Cr mouth
No Name Creek Mouth	816-74998	F	Feb 92 (345); May 92 (323)
Nahas Marsh	816-74984	F	Jan 92 (323); Jan 93 (316); Feb 93 (323) - at Tom Draw
Strike Dam Road	816-74977	M	Jun 91 (222); May 93 (245)
Nahas Marsh	816-74793	F	Jan 93 (295); May 93 (314)

Table 3. Nests of long-eared owls in the Snake River Birds of Prey area in 1994.[a]

Site	Adults Trapped	# Young	# Juv Banded	Fate
Castle Ck Mouth N I	0	1+4 eggs	1	unknown[b]
Castle Ck Mouth N III	2	@3	0	successful
Castle Ck Mouth N V	2	@3	0	successful
Poison Creek Picnic	0	@1	1	?[c]
Sinker Creek Butte North	0	6 eggs	0	failed
Sinker Creek Butte	0	6	6	successful
Sinker Creek Butte South	2	5	3	successful
Strike Dam Marsh South	0	@5	0	successful
Strike Dam Marsh	1	3+1 egg	3	successful
Strike Dam Road West	0	5	5	?[d]
Strike Ditch	0	7	7	successful

[a]Other sites searched with no nests found are: Loveridge Bridge, Bruneau Flats, Crane Falls Sturgeon, Crane Falls Lake, Emigrant Trail South, grove west of Emigrant Trail South, Fossil Creek Mouth, No Name Creek Mouth, Black Sands Creek East, Porter Creek, and Rabbit Springs.
[b] Probably failed; nest did not appear used by a brood.
[c] Young was branched when last seen, 3.5 weeks old.
[d] Young were 3-4 weeks old when last seen, nestlings and branchers.

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Short-eared Owl Mortality Between Mid-nestling Age and Dispersal

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ANNUAL SUMMARY

*I examined mortality in short-eared owls (**Asio flammeus**) between the mid-nestling period and dispersal from the natal area. Twenty-three young from 6 nesting areas were instrumented as nestlings with tarsal-mounted radio transmitters and were monitored until they dispersed from their nesting area. Seven nestlings (30.4%) survived to disperse from their nesting area. Sixteen nestlings (69.6%) died before dispersing. The mean age of death was 20.9 days. Mammalian predation was probably responsible for 5 deaths (31.2%), followed by starvation which was responsible for 4 deaths (25.0%). A variety of mortality factors accounted for the remaining nestling losses.*

OBJECTIVES

1. Document the degree of short-eared owl mortality that occurs between the mid-nestling period (12 days of age) and dispersal (approximately 60 days of age) in the Snake River Birds of Prey National Conservation Area (NCA).

2. Identify the causes of short-eared owl mortality during the nestling and fledgling periods.

3. Determine if a count of short-eared owl nestlings at or near 12 days of age is an accurate measure of reproductive success.

4. Determine breeding adult short-eared owl home ranges in the NCA.

INTRODUCTION

In the Snake River Birds of Prey National Conservation Area, raptor nesting attempts are considered successful if ≥ 1 young reach 80% of the average age at which most young fledge (Steenhof 1987). This corresponds to 20 days for short-eared owls (Clark 1975). However, short-eared owl nestlings leave the nest on foot as early as 12 days of age, well before fledging age (Clark 1975). By the time nestlings are 20 days old, they are well hidden in surrounding vegetation and are extremely difficult to count. This behavior has hindered efforts to measure reproductive success of short-eared owls in the NCA (Lehman et al. 1992). I hoped to address this problem by radio-tracking short-eared owl nestlings between their departure from the nest and dispersal from the natal area to

assess the proportion of nestlings that die before dispersing. If survival is high before dispersal, a brood count in the mid-nestling period might accurately reflect fledging success. If survival is low, reproductive success will have to be determined at 20 days of age, after young have left the nest. This would require that young be located in surrounding vegetation.

Knowledge of adult home range size in the shrubsteppe habitats of southern Idaho also would be useful in locating nests of short-eared owls. Most estimates of short-eared owl home range size are from wetter and perhaps more productive environments, and none are from arid shrubsteppe ecosystems (Holt and Leasure 1993). I hoped to determine home ranges by instrumenting approximately 10 adult short-eared owls.

METHODS

Locating Nests

I located nests in conjunction with Study 3's benchland survey (Lehman et al., this volume). I conducted follow-up surveys in areas where short-eared owls were observed during quadrat surveys, historical nest checks, or incidentally. I conducted surveys at dawn and dusk. Dawn watches typically began at first light, approximately 1 hr before sunrise, and continued until 1 hr after sunrise. Dusk watches began approximately 1 hr prior to sunset and continued after sunset until low light prevented further observations.

During daylight hours, I searched suspected nesting areas to flush adult short-eared owls. I conducted searches within square plots centered on the location of the most recent short-eared owl sighting. Search patterns consisted of parallel line transects spaced at 5 to 20-m intervals, depending on vegetation density. I walked wider intervals in areas with low vegetation density. The effective search area extended 400 m or more in all directions from the center of the plot. Survey crews of 2-4 observers assisted in nest searches. Survey crews walked adjacent parallel transects as a group with a dog walking in front of the crew.

Radio Telemetry

I planned to instrument all nestlings in each nest when the oldest was approximately 12 days old. However, some nests with large asynchronous broods required up to 3 visits to instrument all the nestlings. Nestlings were weighed, banded with a USFWS band on 1 leg, and equipped with a 6.5-g radio transmitter on the other leg. The transmitter contained a mortality circuit that doubled the pulse rate to 60 pulses per min if the transmitter remained stationary for more than 8 hrs. It was manufactured by Advanced Telemetry Systems, Isanti, Minnesota, and had a minimum guaranteed lifetime of 60 days. Nestling age at the time the transmitter was attached was based on visual descriptions of feather development in Holt and Leasure (1993).

I monitored radio-equipped nestlings at 1- to 4-day intervals; however, access restrictions into the Orchard Training Area sometimes prevented such frequent visits. Monitoring typically involved detection of the radio signal to determine the pulse rate of the transmitter. A slow pulse indicated the nestling was still alive. I visited nesting areas at various times of the day, but most visits occurred during late afternoon or at dawn. During every second or third visit, I used the radio signal to approach the owl on foot for visual confirmation of survival. When I could no longer detect the radio signal of a nestling, I expanded the search area out to a diameter of approximately 8 km. I also scanned for radio signals while driving around the study area.

Territorial adult short-eared owls were captured using 3 methods. Initially, I used the method described by Ulmschneider (1992), using a plastic decoy owl and a single mist net. Later during the breeding period, I used a live great-horned owl (*Bubo virginianus*) on a 2-m perch surrounded by 2 mist nets placed in V-shaped arrangement. The mist nets extended 1 m above and below the lure owl. One male short-eared owl was captured with a baited bal-chatri placed under a commonly used perch site. Adult short-eared owls were sexed by color, weight, and behavior. Female short-eared owls are larger and darker than males, and the female is solely responsible for incubation (Holt and Leasure 1993).

As with nestlings, I used tarsal-mounted radio transmitters to instrument adult short-eared owls. However, adults instrumented late in the season were equipped with radios with a 60 pulse/minute rate and no mortality circuit. I planned on tracking adult short-eared owls with 2-3 observers at fixed points and triangulating the location of the instrumented owl with simultaneous bearings. However, various problems, outlined fully in the results section, prevented sufficient data from being recorded.

RESULTS

In conjunction with Study 3, I located 35 occupied short-eared owl nesting areas (Lehman et al., this volume). I found a nest at 14 of these nesting areas. I found the nest at Christmas Mtn Southeast after the nestlings had dispersed from the nest. Seven of the remaining nests failed either during incubation or the early nestling period before the nestlings were old enough to instrument. See Lehman et al. (this volume) for more details on the fate of pairs for which no nest was found.

I instrumented 23 nestlings from 6 nests. Seven instrumented nestlings (30.4%) survived to disperse from their natal nesting area (Table 1). The survivors were from 4 of the 6 instrumented broods. The mean age of dispersal was 52 days (range = 41-67). Juveniles from the same brood did not always disperse from the natal area at the same time. Radio signals could not be detected at a distance ≥ 1.5 km over flat ground if the instrumented owl was perched on the ground. The greatest distance at which a signal was detected by a receiver at an elevated observation point was approximately 3.2 km. No instrumented juveniles were detected by their radio signals after leaving their natal nesting areas.

Sixteen instrumented juveniles (69.6%) died of various causes (Table 2). Fifteen (65.2%) died before dispersing from their natal nesting area. The remains of a fledgling from Artillery Range were located 19.5 km north of its natal area after it dispersed. The cause of death was unknown. Five of the 16 juveniles that died (31.2%), 3 from the Wind Butte nesting area and 2 from Sand Creek North, were probably killed by mammalian predators. The entire brood of 4 (25.5%) from Christmastime nesting area is believed to have died from starvation after the disappearance of the adult female from the nesting area. Two juveniles (12.5%) from the Poen Road West nesting area died from heat stress. They both died during the day on 22 June when the air temperature exceeded 38 C. They were found in sparse vegetation approximately 20 cm tall. Two brood mates survived: 1 that roosted about 20 cm below the ground surface in an old badger (*Taxidea taxus*) burrow, and 1 that was brooded in the nest scrape by the adult female. One juvenile (6.2%) from the Wind Butte nesting area was crushed by a vehicle. One nestling (6.2%) from the Sand Creek North nesting area died after being

Table 1. Surviving juvenile short-eared owls.

Site	Date Radioed	Hatch Date	Age when tagged	Band Number	Radio Freq. (MHz)	Date of Last Location	Age at Last Location
Artillery Range 2	29 Apr	19 Apr	10	2206-30808	166.843	31 May	42
Artillery Range 3	29 Apr	20 Apr	9	2206-30809	167.141	31 May	41
Wind Butte 1	8 May	27 Apr	11	2206-30811	166.879	12 Jun	46
Wind Butte 2	8 May	27 Apr	10.5	2206-30810	166.917	26 Jun	60
Poen Road West 3	20 Jun	9 Jun	11	2206-30827	167.130	15 Aug	67
Poen Road West 4	22 Jun	11 Jun	11	2206-30828	166.950	29 Jul	48
ISA Transect 792 1	30 Jun	16 Jun	14	2206-30829	167.029	15 Aug	60

Table 2. Juvenile short-eared owls that died prior to dispersal.

Owl	Date Radioed	Hatch Date	Age when Tagged	Band Number	Radio Freq.	Date Recovered	Last Obs. Alive	Est. Date of Death	Age at Death	Cause of Death
Artillery Range 1	29 Apr	17 Apr	12	2206-30807	167.060	8 Jun	31 May	4 Jun	48	Unknown cause
Wind Butte 3	8 May	29 Apr	9	2206-30813	166.994	20 May	17 May	20 May	21	Mammalian
Wind Butte 4	12 May	1 May	10.5	2206-30812	167.029	20 May	17 May	20 May	20	Mammalian
Wind Butte 5	12 May	3 May	9	2206-30814	166.755	20 May	17 May	20 May	17	Mammalian
Wind Butte 6	17 May	5 May	12	2206-30815	166.778	12 Jun	31 May	4 Jun	30	Auto
Christunastime 1	4 Jun	22 May	13	2206-30821	166.994	20 Jun	14 Jun	18 Jun	27	Starvation
Christunastime 2	4 Jun	23 May	12	2206-30822	167.029	20 Jun	14 Jun	18 Jun	26	Starvation
Christmastime 3	7 Jun	25 May	12.5	2206-30823	167.730	20 Jun	14 Jun	16 Jun	22	Starvation
Christmastime 4	10 Jun	31 May	10	2206-30824	166.950	20 Jun	14 Jun	14 Jun	14	Starvation
Poen Road West 1	16 Jun	4 Jun	12	2206-30825	166.978	22 Jun	20 Jun	22 Jun	18	Heat Stress
Poen Road West 2	16 Jun	6 Jun	10	2206-30826	167.081	22 Jun	20 Jun	22 Jun	16	Heat
ISA Transect 792 2	1 Jul	17 Jun	14	2206-30830	166.994	13 Jul	11 Jul	12 Jul	25	Unknown
Sand Creek North 1	11 Jul	3 Jul	8	2206-30832	166.730	15 Jul	13 Jul	15 Jul	12	Buried in
Sand Creek North 2	13 Jul	3 Jul	10	not banded	166.778	15 Jul	13 Jul	14 Jul	11	Unknown
Sand Creek North 3	15 Jul	5 Jul	10	2206-30831	166.994	20 Jul	18 Jul	19 Jul	14	Mammalian
Sand Creek North 4	18 Jul	6 Jul	12	2206-30833	167.060	20 Jul	18 Jul	19 Jul	13	Mammalian

buried when a rodent tunnel beneath the nest collapsed. Three juvenile owls (18.7%) died of unknown causes, including 1 of the nestlings found dead in the Sand Creek North nest. Only a few feathers and feet were recovered from the remaining 2: 1 at ISA Transect 792 and 1 at Artillery Range, as mentioned above. The relative proportion of each mortality type is presented in Fig. 1.

Most mortality occurred prior to or near the legal fledging age (20 days). The mean and median age of death were 20.9 and 19 days, respectively. The mean age at which nestling owls were instrumented was 11 days of age. Eight owls (50.0%) died prior to reaching legal fledging age. Survivorship declined steadily until 18 days after owls were radioed (Fig. 2), by which time all survivors had probably fledged.

Seven adult short-eared owls were captured and instrumented (Table 3). The 3 adults captured early in the breeding season all experienced problems which prevented them from being radio-tracked. Two died, and the third experienced a complete radio malfunction. The other 4 adults were captured relatively late in the breeding season, around the first week of June. The Watson North female had a high voltage power line running through her nesting area, which caused radio interference and prevented detection of the signal unless the transmitter was very close to the receiver. I attempted to track the Christmastime male on 14 June with 2 receivers. However, most of the time the signal could only be picked up by the observer positioned at the top of Christmas Mtn. Only a few position fixes were obtained that night. The Christmastime nest failed by 20 June, and the male soon dispersed from the area. We radio-tracked the Christmas Mtn North male from 2200 to 0400 MDT on the night of 22-23

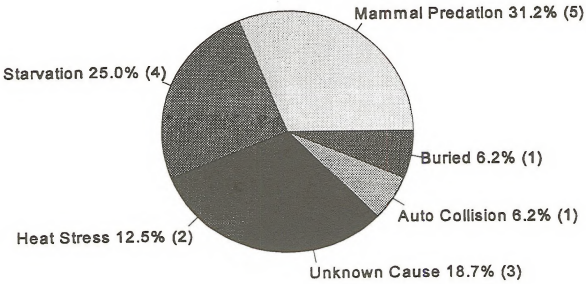

Fig. 1. Magnitude and causes of mortality for 16 juvenile short-eared owls in 1994

Table 3. Captured and instrumented territorial adult short-eared owls.

Nesting Area	Sex	Frequency (MHz)	Band Number	Capture Date	Status
ISA Transect 113 Central	Female	167.042	816-74844	7 Apr	Hit by automobile on 26 Apr
ISA Transect 100 South	Male	166.721	816-74845	11 Apr	Died on 15 Apr due to capture stress
Sand Creek Pond	Male	167.168	2206-30806	16 Apr	Radio malfunctioned prior to 25 Apr
Watson North	Female	166.848	2206-30816	30 May	Radio interference by powerline prevented tracking
Christmastime	Male	167.157	2206-30817	1 Jun	Tracked on 14 Jun
Christmas Mtn	Male	166.721	2206-30818	1 Jun	Tracked on 22 Jun, dispersed by 27 Jun
Watson East	Female	167.110	2206-30820	3 Jun	Missing after nest was destroyed on 16 Jun

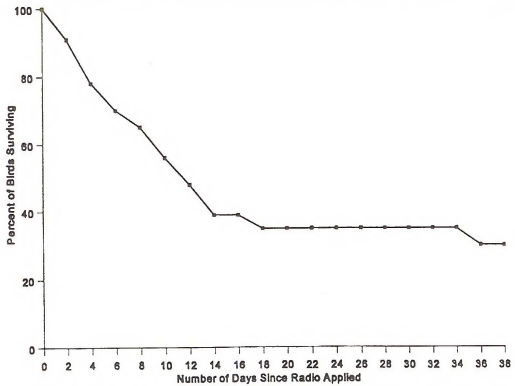

Fig. 2. Survivorship of 23 juvenile short-eared owls in 1994.

June with 3 receivers. However, most of the position fixes contained bearings from only 2 of the 3 receivers. The signal was often difficult to detect when the owl was perched, and most flights were relatively short, which made taking synchronized bearings difficult. This owl was active throughout the entire time period. I returned to track the owl further on 27 June, but could not detect any signal. The young of this owl had already fledged when it was captured, so I believe the owl dispersed from its nesting area between 23 and 27 June. No attempt was made to track the Watson East female until after she stopped brooding young. However, the nest failed and I could not detect her signal after the failure.

DISCUSSION

One of the more difficult aspects of this study was assigning mortality causes to recovered owl carcasses, especially in the case of suspected predation. I could not be certain whether a nestling was killed by a predator or was simply scavenged after death from some other cause. Below, I describe the circumstances surrounding the 2 cases of suspected predation.

Three nestlings that had dispersed by foot from the Wind Butte nesting area were found dead at approximately 0700 MDT on 20 May. Two had been dead < 8 hours. These birds were about 90 m apart, and were were partially consumed. The third had a single large puncture wound to its neck. Three surviving nestlings were located nearby. Another case of mammalian predation was suspected at the Sand Creek North nesting area, where 2 nestlings were found partially consumed and buried within 1 m of the nest. Canine tracks were found near the burial site. In both cases, the fact several brood-mates died at approximately the same time suggests a single cause. Starvation is highly unlikely because there were uneaten prey items in the vicinity of both nests. Also, the brood mates that died of starvation at Christmastime died over a period of several days. Heat stress is unlikely because the Wind Butte juveniles died during a damp night and the Sand Creek North nestlings were shaded by a large shrub. The burial of uneaten owl remains at the Sand Creek North nesting area implicates a mammalian predator. I believe avian predators would have carried an owl carcass farther away from the nest scrape before consuming the carcass.

I assigned starvation to the 4 nestlings at Christmastime for the following reasons: 1) they died in order of increasing age over a period of 4-6 days starting with the youngest bird; 2) 2 carcasses were found in typical day roost sites, an unused badger burrow and the nest; 3) the other 2 carcasses were found at unusually large distances from the nest. One was located > 800 m from the nest scrape, over 4 times as far as any non-fledged short-eared owl I have encountered. I suspect these owls traveled such large distances in search of their parents.

Though the sample size is small, my data suggest that brood counts at 12 days of age are not a good indicator of reproductive success. At least 1 nestling died before dispersal at all of the broods I sampled, and in some cases I observed complete brood failures. The data also suggest that mortality risk is highest while nestlings are still in or very near the nest, and then drops off after they leave the nest to hide in surrounding vegetation. Mortality becomes minimal after the young fledge at about 25 days of age.

I was able to document breeding success at several nesting areas where the nest was never found by observing recently fledged short-eared owls flying at dusk. However, in these cases I could not be certain that complete brood counts were obtained. Several evenings of careful observation often were necessary to detect fledglings. A certain amount of training and experience is necessary to identify the flight silhouettes of recently fledged short-eared owls. Thus, dusk watches were effective in determining breeding success of short-eared owls, but did not provide a measure of productivity.

Short-eared owl breeding behavior was much more conspicuous than in 1993. In 1993, I observed breeding behavior at only 3 sites (Rivest 1993). Unlike 1993, when courtship flights and calls were not observed, they were commonly observed this season, particularly around dusk. Territorial

interactions were also commonly observed between closely spaced adjacent breeding pairs. Based on this year's results, I believe that breeding was indeed sparse last year, and there was not a large population of short-eared owls breeding undetected. I suspect the difference in breeding activity between the 2 years is due to changes in prey abundance. Some short-eared owl populations, especially those dependent on voles (*Microtus* spp.), are synchronized with prey cycles (e.g., Korpimäki 1984). Other populations are nomadic and move between areas with irruptive prey increases (Clark 1975).

Locating the nest in an occupied short-eared nesting area was often difficult because an incubating female sits very tightly on the nest when intruders are nearby. Usually, the female did not flush until an observer had walked within 5 m of the nest. Courtship flights by the male were often the best clue to the nest's location. Most courtship flights by the male were roughly circular in shape and were centered over the nest. Also, I believe use of a dog to help find short-eared owl nests has potential. My dog flushed short-eared owls off 3 nests, including 1 nest that was missed by a crew of 4 observers walking transects spaced 5 m apart. He also located 1 nestling owl that had dispersed from the nest. I believe a dog specifically trained to look for owl nests by scent would be a great asset to any short-eared owl nesting study.

Capture and radio-tracking of adult short-eared owls also proved to be difficult and time consuming. Territorial adults, while often quite aggressive towards the lure owl, were extremely adept at avoiding the mist nets. During observations of the trapping set-up with night vision equipment, it was obvious the owls were able to see the nets from a distance of 2-3 m. Trapping success was highest well after sunset during calm starlit nights with no moon. Cloudy nights also provided good trapping conditions, provided that the trapping site was sufficiently remote from light sources (e.g., a town or city) that would light up the clouds. It is also important to begin tracking instrumented owls shortly after tagging because of their tendency to disperse from the nesting area if a nesting attempt is unsuccessful. At least 3 observers are required to triangulate locations of short-eared owls that are moving about the home range. Observers should find the highest vantage points available and should be well trained to take bearings very quickly when the signal is available. Determination of adult home ranges is important to the design of long-term monitoring strategies. Knowledge of short-eared owl home range size in shrubsteppe habitats would be useful in determining the best sampling strategy.

This study has shown that prefledging short-eared owls suffer from a variety of mortality causes. Without further study and a larger sample size, it is not possible to determine if brood size before dispersal from the nest (before the age of 12 days) can be correlated to reproductive success as measured at legal fledging age (20 days). With further study, it may be possible to correlate observations of dusk flights of recently fledged juvenile short-eared owls to a count of successfully fledged young known through radio-telemetry. However, I believe observations of dusk flights of short-eared owls are highly dependent upon the attentiveness and experience of the observer. The results of this study and the previous year's study indicate the need for long-term study of irregular breeders such as short-eared owls.

PLANS FOR NEXT YEAR

In 1995, I hope to continue the radio telemetry study with emphasis on the survival of nestlings in addition to determining adult home ranges.

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Captive Propagation, Nest Manipulation, and Nesting Behavior of Common Ravens in the Snake River Birds of Prey National Conservation Area

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ANNUAL SUMMARY

*We manipulated and observed nesting common ravens (**Corvus corax**) in the Snake River Birds of Prey National Conservation Area (SRBOPNCA) to determine how to best propagate in captivity and reintroduce endangered social corvids such as the Hawaiian crow (**Corvus hawaiiensis**). Trapping adults or removing first clutches did not reduce the likelihood of breeding, but productivity of nesting attempts subsequent to clutch removal was reduced relative to unmanipulated pairs. Replacement clutches were laid approximately 2 weeks after the first clutch was removed. Only 1 of 3 pairs laid a third clutch after their first 2 were removed. Removal of clutches in one year did not influence the likelihood of breeding the next year. Survival of captive-bred birds was equal to survival of wild nestlings for 1 year. Rearing captive-bred birds with tutors or puppets does not appear to increase their survival, but tutoring tended to increase the rate at which they joined wild conspecifics. Survival increased with increasing release group size. There appears to be considerable dispersal of adults and young from the study area.*

OBJECTIVES

1. Observe the breeding behavior of ravens from nest initiation through chick-rearing.
2. Monitor breeding success and responses of wild ravens to clutch removal, brood reduction, and fostering of young between nests.
3. Compare the survivorship of ravens reared by wild parents to survivorship of ravens reared by humans and released.
4. Assess factors that influence the survivorship and behavior of captive-reared ravens.

INTRODUCTION

We initiated a study in 1993 to assess the responses of ravens to nest manipulations (clutch removal, brood reduction, and brood transfer), and determine optimal captive propagation and reintroduction techniques for endangered corvids (Marzluff and McKinley 1993). Information on breeding productivity and survivorship of tagged birds was also obtained during this effort. Here we report on the second year of this study with an emphasis on responses of breeding ravens to manipulation of their nest contents, survival of wild and captive-reared birds, and factors that influence the behavior and survival of released birds.

METHODS

Field procedures remained as in earlier years (Marzluff and McKinley 1992, 1993). We increased banding and nest monitoring efforts in conjunction with the study of responses to nest manipulations as part of a larger project on the restoration of the Hawaiian Crow in cooperation with the USFWS and the Peregrine Fund, Inc. Field procedures for this portion of the study can be found in Marzluff (1993). In addition, manipulations and observations carried out in the SRBOPNCA are summarized in Appendix A.

As in 1993, we released hand-reared birds in the summer near occupied nests or foraging birds (Tadpole Butte East, Darling International Meat Products) and in the fall near foraging birds (Gantz Avenue, Desert View Estates, Idaho State Prison, Darling International Meat Products). In 1994, we also reared 6 birds with wild tutors and 6 birds using a puppet. Tutored birds were housed in large (3x12x3 m) aviaries with 3-5 wild birds before they were moved to smaller (4x4x2.5 m) release aviaries with a single wild bird. Tutors were not released with the hand-reared birds. We fed puppet-reared birds using a model raven from the time their eyes opened and could focus (approximately 10 days after hatch) until they could feed on their own (approximately 40 days after hatch).

RESULTS and DISCUSSION

Trapping Adults

We used padded leghold traps (#11/2, Raven Specials, BMI Traps, Eastlake, OH) around dead black-tailed jackrabbits (*Lepus californicus*) in attempts to trap nesting adults at 4 sites (Initial Point, Tadpole Butte East, Christmas Mtn Northeast and Range 15 Tower) during nest building and incubation. The breeding male was captured at Initial Point, and the male and female were captured at Tadpole Butte East. The male at Christmas Mtn Northeast had a broken leg and, despite feeding at the bait, was not captured. Captured birds were marked with patagial tags and bred normally at their sites throughout the summer. We subsequently observed the Initial Point male in his territory as late as 10 November.

Extra-pair Copulations and Mate Guarding

Males remained at their nest cliffs during incubation, apparently guarding their mates from extra-pair copulations. We observed extra-pair copulations at 2 sites in 1993 (Tadpole Butte East and Initial Point) and 3 sites in 1994 (Range 15 Tower, Christmas Mtn Northeast and Tadpole Butte East). In all cases the interloping males appeared most often during the few minutes of each day that the territorial males were out of their nesting areas. If breeding males were in attendance they chased interlopers, sometimes successfully, away from the nest. The uncanny ability of interlopers to arrive at the nest just after the territorial male left suggested that nests with fertile, laying females were under continual surveillance by males other than their mates.

Influence of Clutch Removal on Productivity

Removal of clutches did not influence productivity between years. In 1994, we monitored 20 nests that were not manipulated in 1993 and 11 that were

manipulated in 1993. Sites that were previously manipulated showed signs of nest repair as often (81.8%) as control nests (80.0%; $X^2_{(1)} = 0.01$, $P > 0.90$). Fledging success per occupied nest was slightly higher at manipulated sites ($\bar{x}$=3.5 fledglings, $n = 4$, SE = 1.19) than control sites ($\bar{x}$= 2.39 fledglings, $n = 13$, SE = 0.59; $t_{(15)} = 0.89$, $P = 0.39$).

Most pairs laid eggs after we pulled their first clutch, but then experienced poor success. Combining 1993 and 1994, 9 of 13 pairs renested (69.2%). One pair (Range 15 Tower) laid a third clutch in response to our removal of their first 2 clutches. Two other pairs (Initial Point and Christmas Mtn Northeast) did not lay a third clutch after their first 2 were removed. Renesting occurred approximately 2 weeks after the first clutch was removed ($\bar{x}$= 13.5 days, n = 10, SD = 7.4; influenced by 1 outlier of 34 days in 1993). Replacement clutches were smaller ($\bar{x}$= 4.9 eggs, SE = 0.31) than original clutches ($\bar{x}$= 5.6 eggs, SE = 0.16; n = 10 pairs, $t_{(9)} = 2.3$, $P = 0.05$). Combining 1993 and 1994, the number of fledglings per renest was slightly lower ($\bar{x}$= 1.17, n = 6, SE = 0.65) than the number at unmanipulated sites ($\bar{x}$ = 2.76, n = 25, SE = 0.45; $t_{(29)} = 1.63$, $P = 0.11$).

Survival and Resightings of Tagged Individuals

The proportion of tagged birds that were resighted is an estimate of survivorship. This estimate indicates minimum survivorship because some birds not resighted may have dispersed. In this respect, resightings are best used as an indication of retention of birds in the study area. In 1993 and 1994, we searched for tagged ravens ≥1, and often 5-7, days per week. We resighted 31 patagial-tagged individuals banded from 1991-94 ≥1 month post-tagging (Table 1). The maximum resighting interval was 29 months, for a nestling banded in 1991.

Retention, or survival, in the study area was roughly twice as high for adults banded during the winter as for nestlings (Table 2). However, both estimates were much lower than expected if losses were due only to death. Rather, it appears likely that considerable dispersal, even among the older age classes (black-mouthed birds) occurred. This was especially evident after we radio-tagged 13 adults in the winter of 1993-94. Only 1 of 4 was consistently found in the study area (although it did not appear to nest). A second radio-tagged adult returned to the area late this fall. Similarly, 2 of 9 patagial-tagged adults from last winter returned this spring. Site tenacity and survival of breeding adults will be assessed in 1995.

Retention of hand-reared birds released in the summer or fall of 1993 was similar to retention of wild nestlings fledged in 1993 (Table 2; $X^2_{(1)} = 0.001$, $P = 0.975$). Hand-reared birds were fitted with radio-transmitters which allowed us to better determine if death or possible dispersal accounted for lack of resightings. Of the 20 released birds, 17 were not resighted in the study area beyond August 1994. Nine (52.9%) were confirmed mortalities, and 8 (47.1%) may have dispersed or had malfunctioning transmitters.

Post-fledging survival of wild nestlings in 1994 was poor. We placed radio-tags on 10 nestlings (Tadpole Butte East and Desert View Watertower). All nestlings fledged, but 3 of 5 from each nest died shortly thereafter. The dead fledglings at Tadpole Butte East were found dead within a week of fledging near the nest cliff; the other 2 were never seen again and are likely to be dead. A golden eagle (*Aquila chrysaetos*) was commonly near this nest site and may have killed the nestlings, but there was no evidence on the recovered carcasses to suggest the cause of death. The dead fledglings from Desert View were killed by dogs (n = 2) or died from injuries sustained when they became entangled in fishing line (n = 1). The other 2 fledglings dispersed from their natal territory.

Captive Propagation

We removed 50 eggs from 9 nests (Appendix A), hatched 33 chicks, and released 21 fledglings (8 in the summer, 13 in the fall) in 1994.

Table 1. Resightings of marked ravens in the study area ≥ 1 month after tagging. Adults are those ravens with black mouth linings at time of capture. Juveniles are free-flying ravens with partially pink mouth linings at time of capture.

Individual	Type of Tag	Age at Banding	Banding Site	Banding Date	Resighting Date	Resighting Location
1807-38518	patagial	nestling	Christmas Mtn Northeast	05/12/92	12/08/93	Darling International
1807-38597	patagial & radio	nestling	Tadpole Butte East	06/18/93	11/24/93	Darling International
1807-38502	patagial	nestling	Swan Dam Three Poles	06/08/91	11/24/93	Darling International
1807-47748	patagial	nestling	Corder Creek South	06/04/93	12/08/93	Idaho State Prison
1807-38564	patagial	adult	OTA	01/19/93	01/07/94	Darling International
2327-69913	patagial & radio	adult	Darling International	12/31/93	02/10/94	Melba
2327-69914	patagial & radio	adult	Darling International	12/31/93	02/15/94	Melba
1807-38563	patagial	adult	OTA	01/17/93	12/05/94	S. Cole Road
2327-69921	patagial	adult	Darling International	01/09/94	02/10/94	Melba
2327-69918	patagial	adult	Darling International	01/09/94	12/02/94	Kuna Mora Road
2327-69924	patagial	juvenile	Darling International	01/09/94	02/10/94	Melba
2327-69905	patagial	juvenile	Darling International	12/31/93	02/15/94	Melba
1807-38512	patagial	nestling	Initial Point	05/03/92	02/15/94	Baseline Road
1807-47795	patagial	nestling	APC Range 3	06/04/93	02/15/94	Melba
2327-69910	patagial	juvenile	Darling International	12/31/93	02/17/94	Darling International
2327-69904	patagial	juvenile	Darling International	12/31/94	08/25/94	Idaho State Prison
1807-47772	patagial	nestling	Big Baja Pole 116	06/10/94	07/18/94	Idaho State Prison
2327-69912	patagial & radio	adult	Darling International	12/31/93	12/03/94	Barker Road
1807-38595	patagial & radio	nestling	Tadpole Butte East	06/18/93	08/01/94	Idaho State Prison
1807-47903	patagial	nestling	Range 6	06/02/94	08/19/94	Idaho State Prison
1807-38578	patagial & radio	hand-reared	Christmas Mtn Northeast	06/18/93	12/03/94	Darling International
1807-38598	patagial & radio	hand-reared	Idaho State Prison	10/27/93	12/03/94	Initial Point
1807-38571	patagial & radio	hand-reared	Christmas Mtn Northeast	06/18/93	08/06/94	Idaho State Prison
1807-47904	patagial	nestling	Range 6	06/02/94	08/09/94	Idaho State Prison
2327-69909	patagial & radio	juvenile	Darling International	12/31/94	08/14/94	Idaho State Prison
1807-47776	patagial	juvenile	Idaho State Prison	08/17/94	12/06/94	Barker Road
1807-47902	patagial	nestling	Range 6	06/02/94	08/28/94	Idaho State Prison
1807-47741	patagial	nestling	APC Range 3	06/04/93	08/25/94	Idaho State Prison
2327-69914	patagial & radio	adult	Darling International	12/31/93	09/07/94	Robinson Road
1807-47753	patagial	nestling	Fawn Loaf	06/08/93	12/05/94	Barker Road
2327-69917	patagial	adult	Darling International	01/09/94	12/06/94	Barker Road

Table 2. Retention of marked ravens in the SRBOPNCA. Minimum number alive includes all individuals seen in a given year plus those not seen that year, but seen the following year.

Age Class Marked	Number Marked	Number Observed in: 1993	Number Observed in: 1994	Minimum Number Alive in: 1993	Minimum Number Alive in: 1994
1991 Nestlings	28	0	1	1	1
1992 Nestlings	31	1	1	2	1
1993 Nestlings	26	2	4	6	4
1993 Hand-reared	20		3		3
1992-93 Adults	7		2		2
1993-94 Adults	13		@4		@4

Tutoring and puppet-rearing did not significantly affect the survivorship of released ravens. Depending upon the status of 2 puppet-reared birds and 1 non-puppet-reared bird that may have dispersed from the study area, survival of fall-released, puppet-reared birds (n = 6) was 33-66% and survival of fall-released birds reared without a puppet (n = 7) was 71-86%. Combining releases across seasons and including releases of American crows (*Corvus brachyrhynchos*) and black-billed magpies (*Pica pica*), 71.5% of birds reared with tutors (n = 3 release groups) and 54.4% of birds reared without tutors (n = 8 groups) survived the first 3 months after release ($F_{(1,8)} = 0.76$, $P = 0.41$).

Birds reared with tutors tended to integrate with wild birds more quickly than birds reared without tutors. Combining seasons and all 3 species, birds reared without tutors took 20.8 days (n = 8 release groups, SE = 7.6) to integrate, but birds reared with tutors took only 4.2 days (n = 3, SE = 11.6). However, this difference was not significant ($F_{(1,6)} = 1.46$, $P = 0.27$). Releases to be conducted in 1995 will increase our sample size so a more powerful assessment of this effect can be made.

Release group size was correlated with the percentage of the group that survived the first 3 months after release. Group sizes varied from 2 to 5 birds, and survival increased significantly with increasing group size ($r = 0.39$, n = 26 groups, $P = 0.05$).

PLANS FOR NEXT YEAR

We will increase our efforts to capture and tag territorial ravens and nestlings. We will manipulate pairs and breed ravens in captivity as in 1994. This will also enable us to observe nesting behavior during egg laying and follow radio-tagged juveniles after they fledge. Releases will be conducted to complete our assessment of the influence of puppet-rearing and tutoring on subsequent social behavior and survival.

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Appendix A. Productivity, tagging, and manipulation of common ravens in the SRBOPNCA, 1994.

Nesting Area	Nest Built/ Repaired	Pair Present in Territory	Clutch Size		Number of		# Patagial Tagged	# Radio Tagged	Manipulations[a]
			Initial	Renest	Eggs Hatched	Fledglings			
Tadpole Butte East	Yes	Yes	7	-	5	5	0	5	1,5,8
Range 15 Tower	Yes	Yes	6	65	-	-	0	0	2,6,7
ChristmasMtn Northeast	Yes	Yes	-	3	1	-	0	0	3,6,8
Bigfoot Butte	Yes	Yes	5	-	-	-	0	0	2, 8[b]
CSJ Jr.	Yes	Yes	-	-	-	@4	0	0	8
Cindercone Butte	No	No	0	-	0	0	0	0	none
Initial Point	Yes	Yes	5	5	-	-	0	0	2,6,8
Thirst Draw	Yes	Yes	-	-	-	0	0	0	8
Range 11 Tower	No	No	0	-	0	0	0	0	8
Swan Road N. Side	Yes	Yes	-	-	-	-	0	0	8
Fan Marker Range 10	Yes	Yes	@5	0	-	-	0	0	2
Cove Recreation	Yes	Yes	-	-	-	6	6	0	None
Balls Basin	Yes	Yes	-	-	-	-	0	0	None
Wind Caves	Yes	Yes	@3	0	0	0	0	0	2
Corder Creek	Yes	Yes	@4	-	5	-	4	0	None
APC Range 3	Yes	Yes	5	-	-	@4	0	0	None
Grandview Feedlot	Yes	Yes	-	-	@2	-	2	0	None
Tadpole Butte West	No	No	0	-	0	0	0	0	None
Little Joe Cave	No	No	0	-	0	0	0	0	None
Range 6	Yes	Yes	6	-	-	4	4	0	2
Beercase Downstream	Yes	No	-	-	-	0	0	0	8
Can-Ada	Yes	Yes	-	-	-	-	0	0	None
Wind Butte Road	Yes	Yes	7	-	-	0	0	0	None
Big Baha Pole 113-116	Yes	Yes	-	-	-	4	1	0	None

Appendix A. (Cont.)

Nesting Area	Nest Built/ Repaired	Pair Present in Territory	Clutch Size		Number of		# Patagial Tagged	# Radio Tagged	Manipulations[a]
			Initial	Renest	Eggs Hatched	Fledglings			
Simplot Point	Yes	Yes	-	-	-	3	3	0	None
Nipple Draw Upstream	Yes	Yes	-	-	-	0	0	0	None
McDermott	Yes	No	0	-	0	0	0	0	None
Balls Pt Downstream	Yes	Yes	-	-	-	-	0	0	None
Big Baha 238-243	Yes	Yes	-	-	0	0	0	0	None
Moore Road	No	No	0	-	0	0	0	0	None
Mantel	Yes	Yes	-	-	-	-	0	0	None
Range 22 APC	Yes	Yes	-	-	-	4	4	0	None
Tyrrel Island	Yes	Yes	6	-	-	-	0	0	2
Sand Creek	No	No	0	-	0	0	0	0	None
Desert ViewWater Tower	Yes	Yes	-	-	-	5	0	4	8

[a] 1 = visit every 3-4 days to measure growth rate
2 = remove 1st clutch for captive propagation
3 = reduce brood to 2 nestlings
4 = foster nestlings from other nest
5 = trap adults prior to nesting season
6 = remove 2nd clutch for captive propagation
7 = remove 3rd clutch for captive propagation
8 = manipulated in 1993

[b] Renesting attempt abandoned due to military presence.

Habitat Relationships and Breeding Passerine Birds on the Snake River Birds of Prey Area

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ANNUAL SUMMARY

*We surveyed breeding passerine abundances throughout the Snake River Birds of Prey National Conservation Area at 145 sites sampled previously in 1991-1993. Analysis for habitat associations of species was similar to results from previous years: shrub-obligate species were associated with big sagebrush (**Artemisia tridentata**) or saltshrub habitats and disturbance, and grassland species, such as horned larks (**Eremophila alpestris**) and Western meadowlarks (**Sturnella neglecta**) were clustered in disturbance habitats. We monitored outcomes for nests of Brewer's sparrows (**Spizella breweri**) and sage thrashers (**Oreoscoptes montanus**). Brewer's sparrows were successful in fledging young at 11 of 15 nests, and sage thrashers were successful at only 4 of 13 nests. Nesting success was not associated with any local vegetation or landscape characteristics that we measured.*

OBJECTIVE

To determine processes that influence the distribution and abundance of breeding passerine birds in fragmented shrubsteppe habitats in the Snake River Birds of Prey National Conservation Area.

INTRODUCTION

The effect of habitat fragmentation on biological diversity is an important consideration in the conservation of the earth's resources (Wilson 1988) because of detrimental effects on biodiversity and individual species distribution and abundance (Saunders et al. 1991). From previous work in 1991-1993, we demonstrated the influence of

fragmentation of shrubsteppe habitats on the distribution of passerine birds that breed in the Snake River Birds of Prey National Conservation Area (Knick and Rotenberry 1995). In 1994, we began a study to determine the process by which fragmentation influences the productivity of shrub-obligate passerine birds.

We tested the hypothesis that species productivity was independent of habitat and landscape characteristics for 3 species of shrub-obligate passerine birds: Brewer's sparrow, sage sparrow, and sage thrasher. Our objective was to determine causes of nest failure and relationship to fragmentation in shrubsteppe.

STUDY AREA

We conducted our study in approximately 200,000 ha of the Snake River Birds of Prey Area (116° E Long, 43° N Lat). Big sagebrush communities dominate the region in the north and grade into salt shrub communities in the south (Yensen and Smith 1983). Large-scale fires between 1980 and 1989 converted approximately one-half of the shrub communities to grassland areas of cheatgrass (*Bromus tectorum*) and Russian thistle (*Salsola iberica*) (Kochert and Pellant 1986). Primary land-use activities are livestock grazing and military training (Kochert and Pellant 1986). Temperatures during hot, dry summers average 30-36 C during June-August; average amount of annual precipitation at the Swan Falls weather station, located within the study area, is 26.9 cm.

METHODS

Point Count Surveys

We counted birds at 145 sites that had been surveyed for vegetation and birds in previous years (Rotenberry and Knick 1991, Rotenberry and Knick 1992, Knick and Rotenberry 1993). We sampled sites once during 30 April to 24 June between 0600 - 1000 hr on mornings that had little wind (<12 km/hr) and no rain. We recorded the number of all birds seen or heard for an unlimited-radius (Ralph et al. 1994) within a 5-min interval after a 1-2-min waiting period upon arrival at the site; we did not determine estimates of density. Minimum distance between sites was 400 m. Observers participated in a 1-3 week training period before sampling the bird sites.

We examined relationships between bird species and habitat variables by canonical correspondence analysis (CANOCO, ter Braak 1988). Canonical correspondence analysis is a multivariate direct gradient ordination of community variation (our avian species counts) relative to the environment (our habitat variables) (ter Braak 1986). In canonical correspondence analysis, the ordination axes of the set of bird species data are constrained to be linear combinations of the environmental variables, and species are assumed to have a unimodal response to the environmental gradients (ter Braak and Prentice 1988).

Vegetation data from bird count sites were previously sampled during 1991-1994 by Study 5 of the Bureau of Land Management/Idaho Army National Guard Research Project (Knick 1991, 1992, 1993; Watts and Knick, this volume). Variables used in the analysis included percent ground cover of dominant shrub, grass, and exotic annual species. We also included East and North UTM coordinates in the analysis. No landscape variables were used in the analysis of 1994 survey data.

Nesting Surveys

We systematically searched for nests of Brewer's sparrows, sage sparrows, and sage thrashers in sagebrush shrub patches from 16 May - 15 July. Nests with eggs or nestlings were revisited at 1-3 day intervals to determine nesting success and number of fledglings. After hatching, nestlings were weighed to 0.1 g with a Pesola scale. A nest was considered successful if nestlings survived 7 days for Brewer's sparrows (Petersen and Best 1987), 8 days for sage sparrows (Petersen and Best 1987), and 12 days for sage thrashers (Reynolds 1981).

Map coordinates of nests were determined by Global Positioning System (GPS). We processed raw GPS data using differential correction and data

averaging (≥180 positions/location) with an accuracy estimated at <6 m for these combined techniques (August et al. 1994).

We measured percent ground cover of vegetation species within a 25-m radius of the nest site by a 1-m^2 point frame (Floyd and Anderson 1982) at 0, 5, 10, 15, 20, and 25-m distances away from the nest along a transect in each of the 4 cardinal directions. We determined the area, perimeter, and thickness of the patch in which the nest was located from the vegetation map translated from satellite imagery. Accuracy of the satellite image in distinguishing between shrub/nonshrub pixels was 80% (S.T. Knick, unpublished data). We also determined the nearest distance to the patch edge for each nest location. Cell size of the satellite map was 25 m and represents the resolution of our measurements.

We used logistic regression to determine environmental variables associated with successful and unsuccessful nests. Logistic regression is used to model the effects of continuous and discrete independent variables on a binary response (e.g., presence/absence) (McCullagh and Nelder 1989). All local vegetation and landscape variables (Table 1) were initially entered in the logistic regression (PROC LOGISTIC, SAS Statistical Institute 1990) model in a backwards elimination procedure (Manly et al. 1993, Trexler and Travis 1993). At successive steps, the least significant variable was removed if it did not contribute to significant differences ($\alpha < 0.05$) in the model fit to the data until no variables remaining in the model met this criterion.

RESULTS

Point Count Surveys

We sampled 146 sites for counts of breeding passerine birds. Vegetation data available from 134 sites were used in the canonical correspondence analysis. Relationships between bird species abundances and vegetation variables are summarized in Fig. 1. This biplot represents approximate values of the weighted averages of the bird species with respect to the vegetation variables. The numerical axes provide a framework for displaying quantitative relationships among bird species and vegetation variables, but otherwise have no intrinsic meaning.

The first axis represented a bird-vegetation canonical correlation of 0.83, whereas the second represented a correlation of 0.70 (Table 2). Together, they accounted for 75.3% of the bird-vegetation association.

Shrub-obligate species, such as sage and Brewer's sparrows, and sage thrashers were associated with big sagebrush or saltshrub communities (Fig. 1). In contrast, grassland and disturbance species, horned larks and meadowlarks were associated with disturbance vegetation communities (Fig. 1).

Table 1. Local vegetation characteristics and landscape attributes used in logistic regression analyses to develop resource selection models for breeding passerines in shrubsteppe habitats, southwestern Idaho.

Variable	Description
Winterfat	Percent ground cover
Shadscale	Percent ground cover
Russian thistle	Percent cover (indicator of disturbance)
Total grass cover	Percent cover of Sandberg's bluegrass, six-weeks fescue, bottlebrush squirreltail, and cheatgrass combined
Patch area	Area of shrub patch size, determined from GIS
Patch perimeter	Perimeter of shrub patch, determined from GIS
Patch thickness	Thickness of shrub patch, determined from GIS

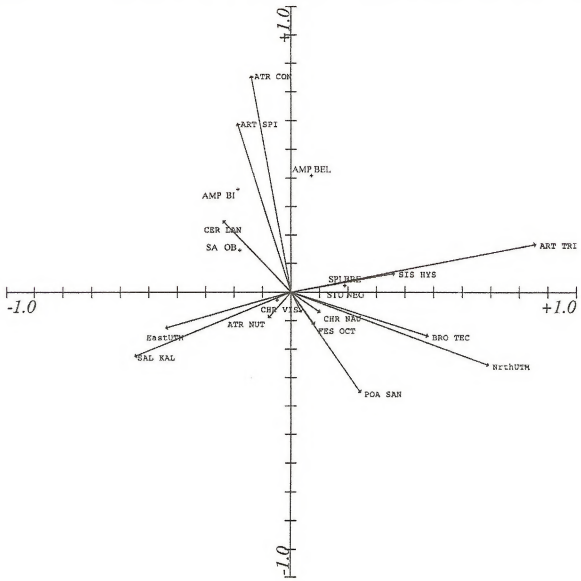

Fig. 1. Biplot of canonical correspondence analysis for birds species and percent ground cover of vegetation at survey sites. Birds species plotted were Brewer's sparrows (SPI BRE), sage sparrow (AMP BEL), black-throated sparrow (AMP BIL), and rock wren (SA OB). Vegetation species plotted were big sagebrush (ART TRI), shadscale (ATR CON), bud sagebrush (ART SPI), winterfat (CER LAN), Nuttall saltbush (ATR NUT), green rabbitbrush (CHR VIS), gray rabbitbrush (CHR NAU), cheatgrass (BRO TEC), Sandberg's bluegrass (POA SAN), bottlebrush squirreltail (SIS HYS), sixweeks fescue (FES OCT), and Russian thistle (SAL KAL). Also included were North and East UTM coordinates.

Table 2. Canonical correspondence analysis of bird species and percent cover values of vegetation at 134 sites. Numbers of birds were counted at each site during 1994; vegetation was sampled in previous years.

	Canonical Correspondence Axis			
	1	2	3	4
Eigenvalues	0.288	0.125	0.049	0.037
Species-environment correlations	0.826	0.704	0.512	0.400
Cumulative percentage variance				
of species data	15.5	22.2	24.9	26.9
of species-environment relation	52.5	75.3	84.1	90.9
Sum of all unconstrained eigenvalues	1.854			
Sum of all canonical eigenvalues	0.548			

Nesting Surveys

We located 6 sage sparrow nests, 19 Brewer's sparrow nests, and 16 sage thrasher nests. Only nest characteristics of Brewer's sparrows and sage thrashers were statistically analyzed for habitat associations of success because of sample sizes.

Brewer's sparrows were successful in fledging young at 11 of 15 nests. None of the local vegetation and landscape variables that we measured were associated with successful nests (Table 3).

Sage thrashers were successful in fledging young at only 5 of 14 nests. However, similar to Brewer's sparrows, none of the local vegetation and landscape variables we measured were associated with successful nests (Table 3).

DISCUSSION

The habitat associations derived from the canonical correspondence analysis were similar to those derived in previous years. Shrub-obligate species were associated with sagebrush or, to a lesser degree, saltshrub communities. In contrast, grassland and disturbance species, horned larks and meadowlarks were associated with disturbance vegetation communities.

Nesting success for Brewer's sparrows and sage thrashers was not related to any local vegetation or landscape characteristics that we measured. Sage thrashers had very low nest success, and we will attempt to determine causes in future work. We also caution that this was the first year of our study of productivity of shrubsteppe birds, and the results should be considered preliminary.

We earlier established the pattern of species distribution relative to fragmentation (Knick and Rotenberry 1995) but do not know the specific mechanisms by which fragmentation influences shrubsteppe species. Dispersal and reproductive rates of species and their degree of specialization and dependence on the fragmented resource (Urban and Shugart 1984, Fahrig and Paloheimo 1988), when coupled with patch size and interpatch distance (connectivity) of the habitats (Gardner et al. 1987, Burkey 1989) dictate benefits or loss due to habitat fragmentation. Birds in fragmented habitats have exhibited lower reproductive rates, higher predation rates, and higher rates of parasitism (Wilcove 1985, Temple and Cary 1988, Yahner and Scott 1988, Johnson and Temple 1990, Robinson 1992, Porneluzi et al. 1993, Paton 1994), and these mechanism all may operate in shrubsteppe habitats.

Previous research has documented microhabitat characteristics of nest placement and within territory habitat structures for numerous species within shrubsteppe habitats (e.g., Rich 1980a, 1980b,

Table 3. Coefficients in logistic regression analysis of local vegetation and landscape characteristics associated with nesting success for Brewer's sparrows and sage thrashers.

	Step	Variable removed	Number in	Wald χ^2	Pr> χ^2
Brewer's sparrows					
	1	Thickness	9		
	2	Perimeter/area	8		
	3	Winterfat	7		
	4	Russian thistle	6	0.00005	0.9944
	5	Cheatgrass	5	0.000884	0.9763
	6	Sagebrush	4	0.000294	0.9863
	7	Grasses	3	0.00042	0.9836
	8	Perimeter	2	0.00106	0.9741
	9	Area	1	0.3337	0.5635
	10	Distance to grass	0	2.3750	0.1233
Sage thrashers					
	1	Thickness	9		
	2	Sagebrush	8	2.285E-8	0.9999
	3	Area	7	0.000011	0.9973
	4	Perimeter	6	0.00197	0.9646
	5	Winterfat	5	0.000149	0.9903
	6	Distance to Grass	4	0.0135	0.9075
	7	Cheatgrass	3	0.0643	0.7999
	8	Russian thistle	2	0.5211	0.4704
	9	Perimeter/area	1	0.8870	0.3463
	10	Grasses	0	2.8961	0.0888

Reynolds 1981, Petersen and Best 1985a, Petersen and Best 1985b, Winter and Best 1985, Rotenberry and Wiens 1980a, Rotenberry and Wiens 1980b). However, interaction of landscape characteristics and processes of bird population dynamics have been difficult because of the inability to quantify attributes such as patch size and habitat evenness at large spatial scales more suited to management strategies. In this study, we now are examining habitats at both local and landscape scales to draw conclusions on structure of avian communities and species distribution and productivity.

PLANS FOR NEXT YEAR

We will repeat point counts with emphasis on sites surveyed in previous years. Because shrubsteppe birds in our study were influenced by landscape characteristics, we will identify sites in marginal habitats and attempt to determine mechanisms limiting the presence of birds. We will increase our search effort to obtain larger sample sizes of nests for analysis of productivity relative to local and landscape characteristics.

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Agricultural Coverages in the Snake River Birds of Prey National Conservation Area

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ANNUAL SUMMARY

This report summarizes the various agricultural coverages available for use in the Snake River Birds of Prey National Conservation Area (NCA). It describes the methods and source materials used, as well as the geographic extent, date of creation, and time frame for each agricultural coverage. Although the maps illustrate only the Integration Study Area (ISA), the full geographic extent of most of the digital coverages includes the NCA. This report serves as a reference to the research being conducted by the Bureau of Land Management/Idaho Army National Guard project.

INTRODUCTION

Agricultural coverages in use by the Bureau of Land Management/Idaho Army National Guard BLM/IDARNG research project in the Snake River Birds of Prey National Conservation Area (NCA) were assembled between 1979 and 1993. Some coverages were produced in support of research, whereas others were done by other agencies for their specific purposes. Each has specific use(s) and may or may not be directly compatible with other agricultural coverages produced using other methods, source materials, or at other time periods. This paper is a reference for the compatibility and use of these agricultural coverages. The geographic extent, source, and resolution of each coverage are shown in Table 1.

Definitions of agriculture used by each of the coverages tend to vary. The 1979 vegetation map uses the terms old and new agriculture, whereas the 1991 habitat map only has one agriculture category. Table 2 summarizes definitions associated with each coverage.

BACKGROUND

The 1979 Vegetation Map

The 1979 vegetation map (Fig. 1) was created from interpretation of 1:31,680 scale color aerial photographs taken in July 1976. Homogeneous stands of shrubsteppe vegetation were delineated on the aerial photographs and transferred to 7.5-min United States Geological Survey (USGS)

Table 1. Description of agricultural coverages in the NCA.

Coverage	Geographic Extent	Sources	Resolution of the Data	Reference(s)
1979 Vegetation Map	BPSA 1977[a]	1976 Color Aerial Photography Vegetation Sampling Field Verification	16 ha	Johnson et al. (1980) Johnson and Nydegger (1985) Quinney et al. (unpublished)
1979 Classified Image	NCA ISA	1979 Landsat Multispectral Scanner satellite imagery	57 m	Zarriello et al. (1994)
Snake River Basin Adjudication Agriculture Map (1986)	NCA ISA	1984 & 1986 Landsat Multispectral Scanner satellite imagery 1986 Color Infrared Photography	57 m	Morse et al. (1990)
Combined Agricultural Strata Map (1991)	ISA	1990-1991 Landsat Thematic Mapper satellite imagery 1987 Aerial Photography	screen digitized (unknown)	Zarriello
1991 Habitat Map	NCA ISA	1990-1991 Landsat Thematic Mapper satellite imagery	25 m	Knick et al. (1992, 1993, 1994)
Bureau of Reclamation Agriculture Map (1993)	NCA ISA	1986 Color Infrared Photography Field Verification	unknown	Bureau of Reclamation/ IDWR personnel

[a]Birds of Prey Study Area 1977

Table 2. Definition of agricultural terms relating to agricultural coverages in the NCA.

Coverage	Agricultural Terms	Definitions and Comments
1979 Vegetation Map	Old and New Agriculture	Old - farmed areas; gravity irrigation; small fields; fence rows New - farmed areas; sprinkler irrigation; large fields; no fence rows
1979 Classified Image	Non-fallow Agriculture	Non-fallow - growing crops
Snake River Basin Adjudication Agriculture Map (1986)	Irrigated, Non-irrigated, and Dryland Agriculture	Irrigated - water applied to crops Non-irrigated - not farmed Dryland - no water applied to crops
1991 Habitat Map	Non-fallow Agriculture	Non-Fallow - growing crops
Combined Agricultural Strata Map (1991)	Agriculture and Non-agriculture	Agriculture - all identified cropland Non-agriculture - non-cropland
Bureau of Reclamation/IDWR Agriculture Map (1993)	Surface or Gravity Irrigated and Fallow	Surface - surface irrigated in 1993 Gravity - gravity irrigated in 1993 Fallow - no growing crops in historical cropland

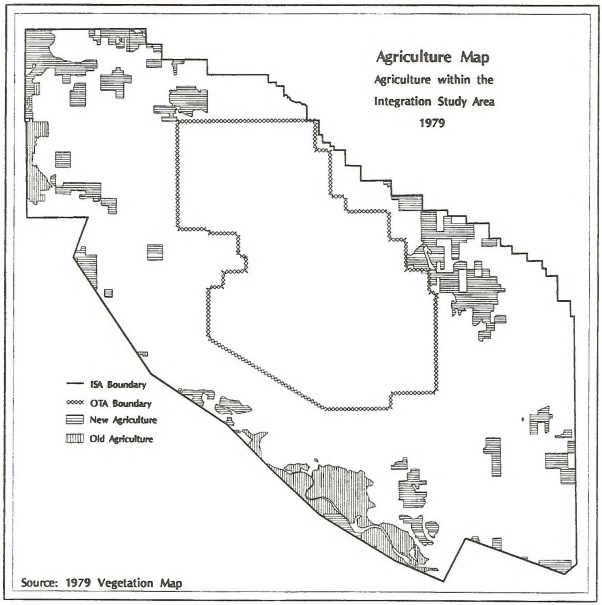

Fig. 1. Agriculture shown on the 1979 Vegetation Map

topographic maps. Type lines were verified, and at least 1 site in each stand was sampled in 1977 and 1978. The map was first published in 1979 (U.S. Dep. Inter. 1979). Boundaries between vegetation stands were further ground-truthed and updated in 1979 and 1980 (Johnson et al. 1980). Although vegetation was sampled during the process, agricultural areas were not sampled (Johnson et al. 1980, Johnson and Nydegger 1985, Quinney et al., unpubl.).

The agriculture depicted by the 1979 vegetation map is divided into 2 categories - old agriculture and new agriculture. This is the only 1 of our agricultural coverages which has these categories. Old agriculture was "(F)armed areas; gravity irrigation; small fields; fence rows," whereas new agriculture is "(F)armed areas; sprinkler irrigation; large fields; no fence rows" (U. S. Dep. Inter. 1979). Each of these 2 categories includes fallow and non-fallow cropland. Fallow cropland is not growing crops during a specific season or year, whereas non-fallow cropland is growing crops in a given season or year. There is no distinction between fallow or non-fallow within the 2 categories in this dataset (Nick Nydegger, IDARNG and Karen Steenhof, National Biological Service pers. commun.).

The 1979 Classified Image

Incidental to the burn mapping project (Zarriello et al., this volume), I mapped non-fallow agriculture for 1979 (Fig. 2). This was accomplished by using 2 Multispectral Scanner (MSS) scenes from May and September 1979, as shown in Table 3. These MSS scenes were geometrically corrected and rectified using the GRASS 4.0 programs (i.points, and i.rectify, GRASS 4.0, U.S. Army Corps Engineers 1991).

I performed a supervised classification on all 8 bands of the 2 MSS scenes using GRASS 4.1 programs (GRASS 4.1, U.S. Army Corps Engineers 1993). The training set for the habitat classification consisted of 592 points sampled on the ground for the 1979 vegetation map. These points were converted to a signature seed file using the program i.gensig in GRASS 4.1. I created an agriculture and water signature seed file with the program

Table 3. In-house satellite imagery used in defining agriculture coverages.

Path/Row	Date	Scene-ID
Multispectral Scanner satellite imagery		
44/30	12 May 1979	LM83043317475X0
44/30	15 Sept 1979	LM83055917463X0
41/30	20 Apr 1987	LM85114517490X0
41/30	27 Sept 1987	LM85130517530X0
41/30	24 May 1988	LM85154517562X0
Thematic Mapper satellite imagery		
41/30	11 May 1989	Y5189717543X0
41/30	3 Sept 1990	Y5264917484X0
41/30	3 March 1991	Y5258517473X0

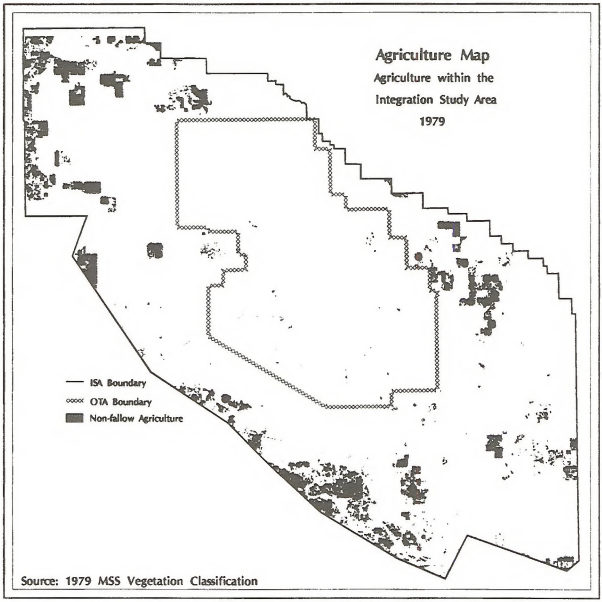

Fig. 2. Agriculture shown on the 1979 Classified Image

i.class. To facilitate comparisons with the 1991 habitat map, only non-fallow agriculture was selected. I subsequently used the 2 signature seed files in a supervised maximum-likelihood discriminant analysis classification (i.maxlik, GRASS 4.1, U.S. Army Corps of Engineers 1993).

The Snake River Basin Adjudication Agricultural Coverage

This coverage (Fig. 3) was produced for the Snake River Basin Adjudication (SRBA). The coverage was begun in 1986 and completed in 1990. Of the 15 MSS scenes, 14 were from 1986 and 1 was from 1984. The classification process was described by Morse et al. (1990), and was done by the Idaho Department of Water Resources (IDWR). It involved creating an unsupervised classification of each county in the SRBA, stratifying the agricultural areas, and using a post-processing algorithm for determining irrigated agriculture. The goal of this project was to depict all irrigated agricultural lands in the area of the SRBA so that all agricultural water claims could be checked. Agriculture is in 2 categories and reflects all the agricultural lands, fallow and non-fallow combined, in 1986.

The 1991 Habitat Map

The 1991 habitat map (Fig. 4) produced by Knick et al. (1992, 1993, this volume) has a non-fallow agriculture category. The map was produced by the classification of 2 Thematic Mapper (TM) satellite images, early September 1990 and late March 1991, as shown in Table 3. The scenes were classified together and the resulting agriculture category is a combination of spectral reflectance classes from both dates.

This vegetation map depicts only non-fallow agriculture, and has no other designation of agriculture. Fallow generally appears in either the grassland or disturbed categories.

The Combined Agricultural Strata Map

The combined agricultural strata map (Fig. 5) was a product of a variety of source data. The digital agriculture data from the 1979 vegetation map was used as a starting point. I then used the same TM satellite imagery as for the 1991 habitat map, and 1987 1:24,000 black and white aerial photography as visual guides with changes made by screen digitizing in GRASS 4.0 on the TM images. The changes were transferred to ARC/INFO and incorporated into a new agriculture coverage. This coverage includes all the fallow and non-fallow agriculture which is shown by the various sources. This was only completed for the ISA.

The Bureau of Reclamation/IDWR Agricultural Coverage

The Bureau of Reclamation/IDWR agricultural coverage (Fig. 6) is the most recent depiction of agriculture in the NCA. Agriculture categories were interpreted from 1986 1:40,000 color infrared photographs and compiled on 7.5-min 1:24000 USGS topographic maps after being photo-reduced to the same scale. These compiled maps were then ground-truthed in 1993 and digitized. This mapping project began as an irrigated lands map, but has evolved into a land cover/land use map, which includes categories for sprinkler or gravity irrigation, and fallow. In the NCA Ada, Canyon, and Owyhee counties are completed and have been obtained. Other counties will be completed until the entire Snake River Basin is done. Study 1 personnel are verifying this map and indicate that this is the most accurate representation of the agriculture in the ISA during the period of our research.

CONCLUSION

There are many different agricultural coverages available in the NCA. The coverages vary widely in their depiction and definition of agriculture, and careful thought must go into their use. For example, all agriculture depicted on the 1979 vegetation map is combined non-fallow and fallow, and cannot be directly compared to the agriculture in the 1991 habitat map which depicts only non-fallow

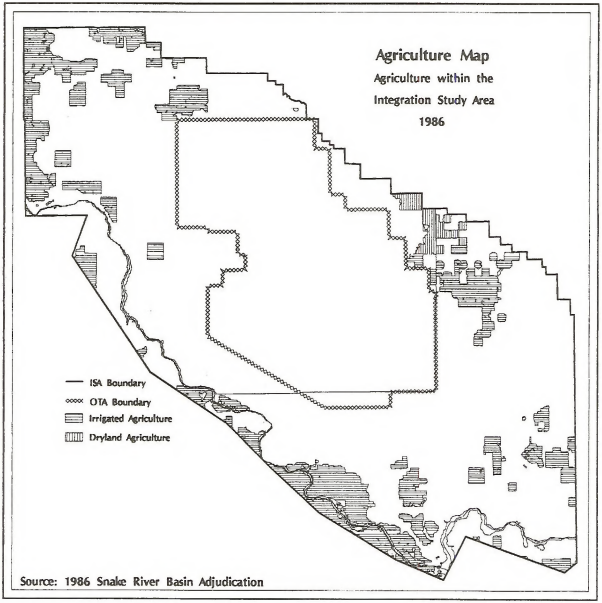

Fig. 3. Agriculture shown on the Snake River Basin Adjudication Agriculture Coverage

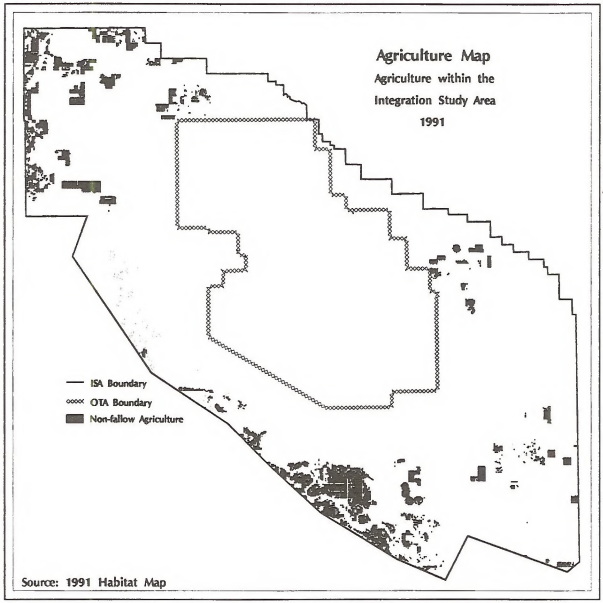

Fig. 4. Agriculture shown on 1991 Habitat Map

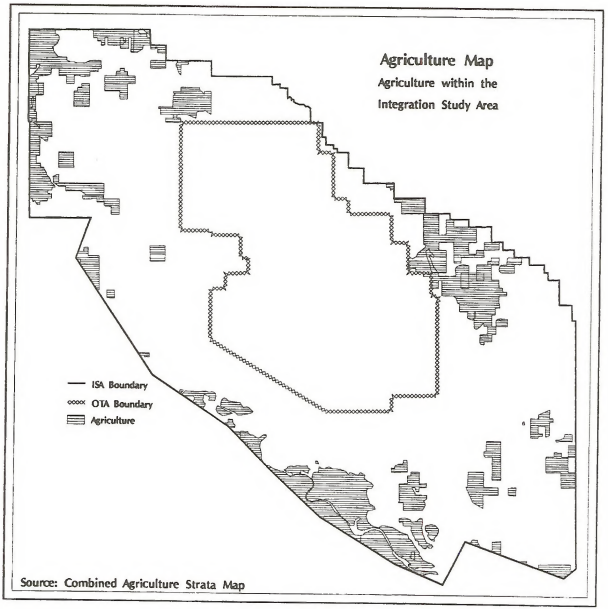

Fig. 5. Agriculture shown on the Combined Agricultural Strata Map

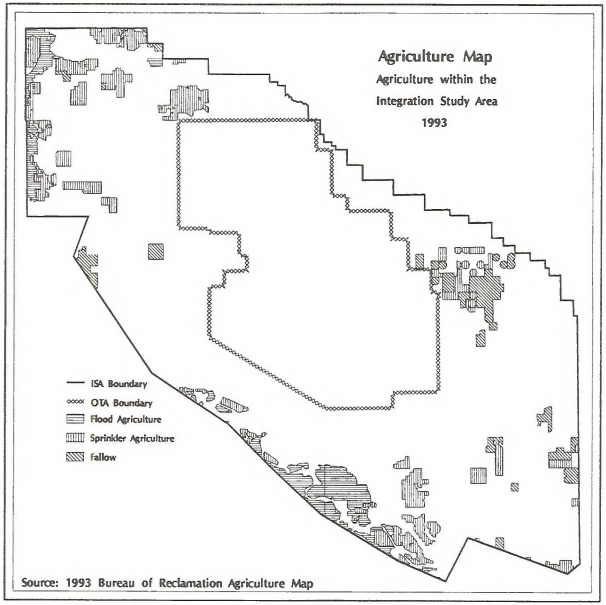

Fig. 6. Agriculture shown on the Bureau of Reclamation Agriculture Map

agriculture. The 1979 vegetation map is also limited to the Birds of Prey Study Area 1977, which does not fully coincide with the NCA or ISA.

Note that agriculture is dynamic from year to year, and we have no way to update the agriculture strata or fallow vs. non-fallow on a yearly basis. Also note, the 1991 habitat map, 1979 classified image, and to a lesser extent the SRBA agricultural coverage, are the only coverages in which heterogeneity, such as small fallow drainages, roads, or riparian areas in an agricultural field are represented. All other coverages are broad-scale approaches.

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Producing a Burn/Disturbance Map for the Snake River Birds of Prey National Conservation Area

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ANNUAL SUMMARY

This is the fourth year of long-term studies in the Bureau of Land Management's global climate change research. This year's research focused on change detection over a longer period of time, versus a yearly time series as had been attempted in the past with limited success (Kramber 1992, Zarriello et al. 1993).

In an attempt to develop a burn/disturbance map for the Snake River Birds of Prey National Conservation Area (NCA), this year's efforts focused on using a previously produced vegetation map (1979) and Multispectral Scanner (MSS) satellite imagery that bracket the time period of greatest wildfire incidence (1981-91).

Two sources of data (1979) were used for this analysis. The first was a previously compiled 1979 vegetation map, and the second was a vegetation classification of 2 temporal MSS scenes for 1979. Change from shrub habitat in 1979 to grass/exotic annual habitat in the 1991 habitat map reflected burn/disturbance.

Because the 1991 habitat map is only fully completed within the Integration Study Area (ISA), this is the limit of the current analysis. The eastern portion of the NCA should be completed in March 1995.

OBJECTIVE

To create a burn/disturbance map in the Snake River Birds of Prey National Conservation Area (NCA) for the period of greatest interest (1981-1991).

INTRODUCTION

Although annual Bureau of Land Management (BLM) fire maps exist for the NCA study area, they contain 2 sources of error. First, there were no annual BLM fire maps produced for the Orchard Training Area (OTA) (Fig. 1). Second, the BLM fire boundaries were acquired during low-level fixed wing flights, then transferred to 7.5-min United States Geological Survey 1:24,000 topographic maps without ground verification and/or correction. This led to mapping errors in the BLM fire maps. Where aerial photos were available for verification, corrections of $\geq$1.6 km were made in some fire boundary locations.

Throughout the previous 3 years of BLM's global climate change research, we collected data for historical weather and fire patterns in the NCA and attempted to map burns on an annual basis using Multispectral Scanner (MSS) satellite imagery with a variety of classification methods and change detection techniques (Knick 1991, Kramber 1992, Zarriello et al. 1993). These methods were determined to be unacceptable in correcting annual BLM fire maps or creating annual OTA fire maps.

This year's efforts focused on using change detection over a longer period of time. The period of greatest interest (1981-1991) can be bracketed by using the 1979 vegetation map and/or 1979 MSS satellite imagery and subsequent overlay with the 1991 habitat map to determine total disturbance.

METHODS

Study Area

The NCA (116° E Long, 43° N Lat) includes approximately 195,325 ha of Great Basin desert rangeland in southwestern Idaho. Livestock grazing and military training are the primary land-use activities (Kochert and Pellant 1986). Once predominantly shrubland, approximately one-half of the shrubland in the NCA has burned since 1980 (Kochert and Pellant 1986). Burned shrublands now persist as exotic annual grasslands.

1979 Base Data

In 1979, a vegetation map was produced for the NCA (Johnson et al. 1980, Johnson and Nydegger 1985, Quinney et al. unpubl.). The 3-year project combined the interpretation of color aerial photography (scale 1:31,680), and ground-truthing to define habitat boundaries on 7.5-min United States Geological Survey 1:24,000 topographic maps. We aggregated habitat categories into a shrubland/grassland habitat map of the NCA, which we then used as 1 source of base data in the change detection.

The second source of 1979 data was MSS satellite imagery. Two 1979 MSS satellite images were used in the current analysis, 12 May and 15 September 1979. These MSS scenes were geometrically corrected and rectified using the GRASS 4.0 programs (i.points, and i.rectify, GRASS 4.0, U.S. Army Corps Engineers 1991).

We performed a supervised classification on all 8 bands of the 2 MSS scenes using GRASS 4.1 programs (GRASS 4.1, U.S. Army Corps Engineers 1993). The training set for the classification consisted of points sampled on the ground for the 1979 vegetation map. These points were converted to a signature seed file using the program i.gensig in GRASS 4.1. An agriculture and water signature seed file was created with the program i.class. The 2 signature seed files were subsequently used in a supervised maximum-likelihood discriminant analysis classification (i.maxlik, GRASS 4.1, U.S. Army Corps of Engineers 1993).

1991 Habitat Map

The 1991 habitat map (Knick et al. 1992) is used as the later vegetation classification in the habitat change detection. The map was produced by the

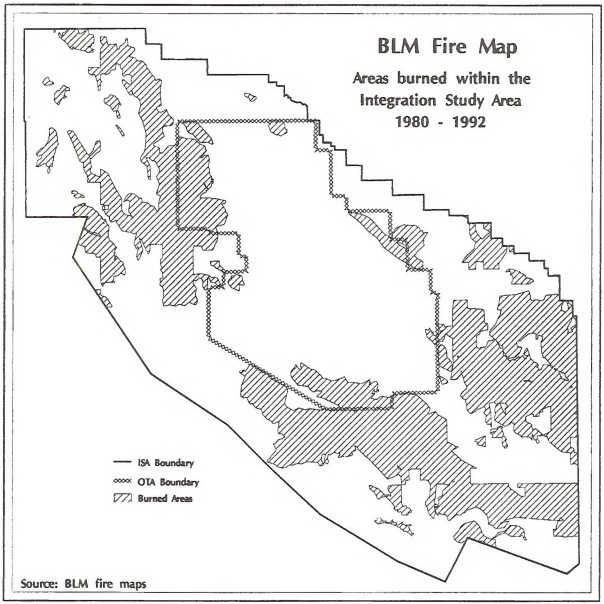

Fig. 1. Composite of annual BLM fire maps from 1980-1992. Absence of burned areas in the OTA reflects lack of mapping information for this area.

classification of 2 Thematic Mapper satellite images taken in early September 1990 and late March 1991. The 2 scenes were classified using a nonparametric discriminant function analysis (PROC DISCRIM, SAS Statistical Institute 1988, 1990). A training set was made up of ground verified points. This resulted in a supervised classification of the NCA which could easily be aggregated into general shrub, grass, and disturbed categories.

Change Detection

The habitat change detection was accomplished by digitally overlaying each of the 1979 base maps with the 1991 habitat map. The digital overlay of the maps was done in the ARC/INFO GRID module (GRID Command References, Environmental Systems Research Institute 1992). The digital overlay was accomplished by converting the 3 separate maps from their respective formats to 100-m grid cells.

The 1979 vegetation map was converted from a polygon coverage to a grid image using the command polygrid. The MSS classified image was resampled from 57-m to 100-m grid cells using the resampling program in GRID. The 1991 habitat map was converted from 25-m grid cells to 100-m grid cells using the same resample program.

The 1979 base data was digitally overlaid on the 1991 habitat map using the ARC/INFO command combine in the GRID module. Areas classified as shrub habitat in 1979 but subsequently classified as grass/exotic annual habitat in the 1991 habitat map were categorized as burned/disturbed areas. This produced 2 separate maps of burned/disturbed regions in the NCA based on the 2 sources of 1979 data.

RESULTS

The results of these map overlays for the Integration Study Area (ISA) are shown in Figs. 2 and 3, and separately for the OTA in Figs. 4 and 5. There are definite similarities and differences between the 2 methods used. Results of change detection by habitat within each of the source maps are summarized in Table 1 for the ISA, and Table 2 for the OTA. Table 3 shows total change within the ISA excluding the OTA in comparison to the BLM fire maps.

DISCUSSION

Our research (Kramber 1992, Zarriello et al. 1993) has shown that in grass/exotic annual environments disturbed by fire, overgrazing, vehicle tracking, or other large-scale disturbance it is difficult to detect any vegetation change. These environments will most likely return to grass/exotic annual habitat quickly. On the other hand, a dense shrub habitat disturbed by fire, overgrazing, vehicle tracking, or other large-scale disturbance will be replaced by grass/exotic annual habitat, and must be undisturbed for many years before beginning to re-inhabit the area (Yensen 1982). For this reason, long-term shrub to grass/exotic annual change detection can be valid.

The reliability of this change detection technique is directly related to the accuracy of the source data. Each method, whether using the 1979 vegetation map or the classified 1979 MSS satellite imagery has limitations. Even the 1991 habitat map, when aggregated into broad shrub/grass/disturbed categories, is still only about 80% accurate (Knick et al., this volume).

Inspection of 2 change-images suggested that some areas with obvious BLM fire scars were shown as having been burned/disturbed very little. This generally occurs in areas in which the existing habitat is grass. This can be partially explained by the quick return to existing grass/exotic annual habitat. Other reasons include the way the 1979 data base was created.

On the 1979 vegetation map, areas of < 16 ha were not mapped (Quinney et al., unpubl.). In comparison, areas were mapped to a size of 0.006 ha in the 1991 habitat map. Therefore, shrub patches in previously burned areas (areas where cheatgrass/exotic annuals existed and dominated in 1979) are not evident in the 1979 vegetation map. This leads to some very homogeneous areas of unburned/undisturbed on the burn/disturbance map using the 1979 vegetation map. Some of these

Table 1. Habitat change detection by source of base data in the ISA.

Habitat Change (1979-1991)	1979 Vegetation Map (ha)	1979 Classified Image (ha)
Shrub - Grass	61,283	80,102
Shrub - Disturbed	15,655	16,510
Grass - Disturbed	2,031	652

Table 2. Habitat change detection by source of base data in the OTA.

Habitat Change (1979-1991)	1979 Vegetation Map (ha)	1979 Classified Image (ha)
Shrub - Grass	23,291	26,371
Shrub - Disturbed	6,373	6,680
Grass - Disturbed	1,116	6

Table 3. Total habitat change from 1979-1991 in comparison to the BLM fire maps.[a]

	1979 Vegetation Map (ha)	1979 Classified Image (ha)
Habitat Change within the BLM Fire Boundaries	32,495	34,489
Habitat Change outside the BLM Fire Boundaries	15,694	29,718
Total Habitat Change	48,189	64,207

BLM Fire Maps Total: 55,356 ha

[a]ISA excluding the OTA

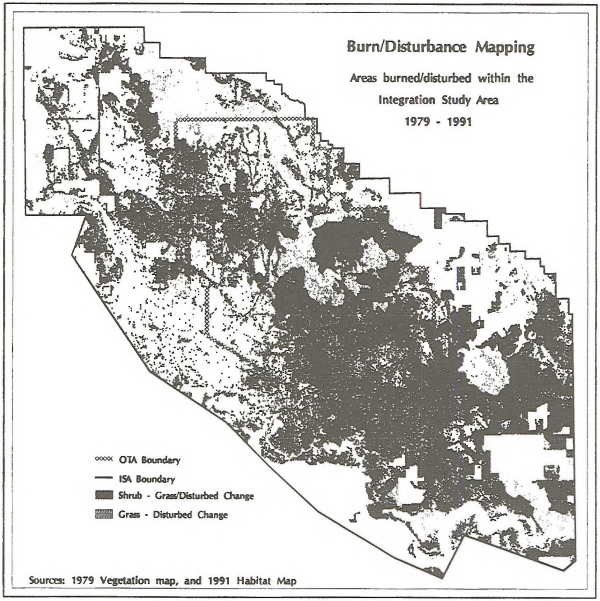

Fig. 2. Areas of burn/disturbance in the ISA using the 1979 vegetation map as base data.

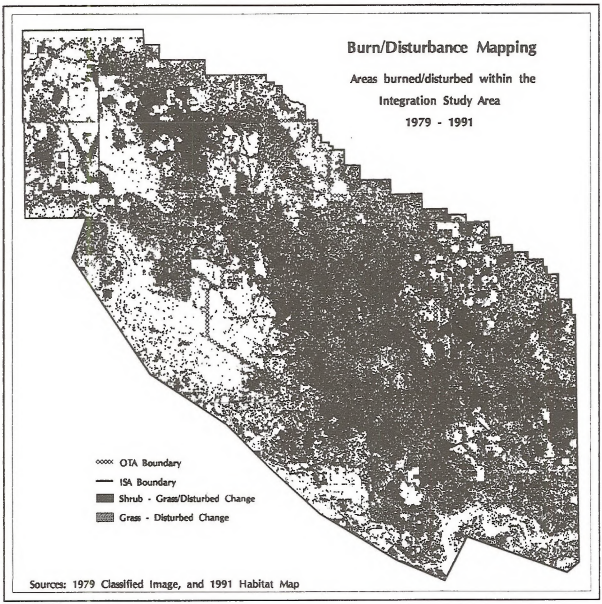

Fig. 3. Areas of burn/disturbance in the ISA using the 1979 classified image base data.

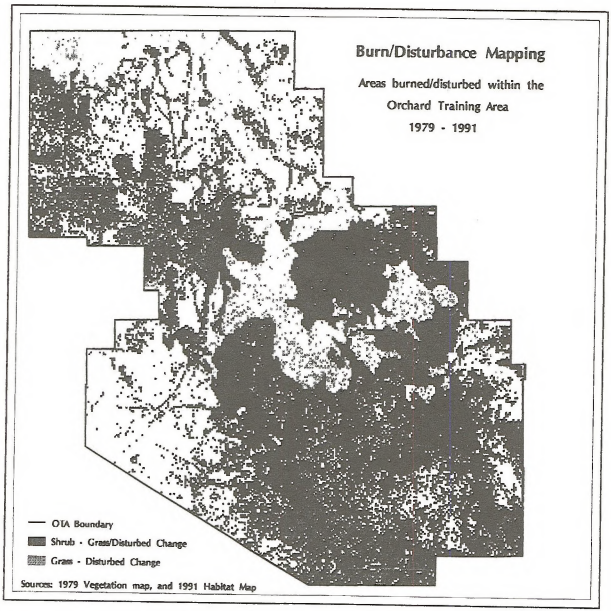

Fig. 4. Areas of burn/disturbance in the OTA using the 1979 vegetation map as base data.

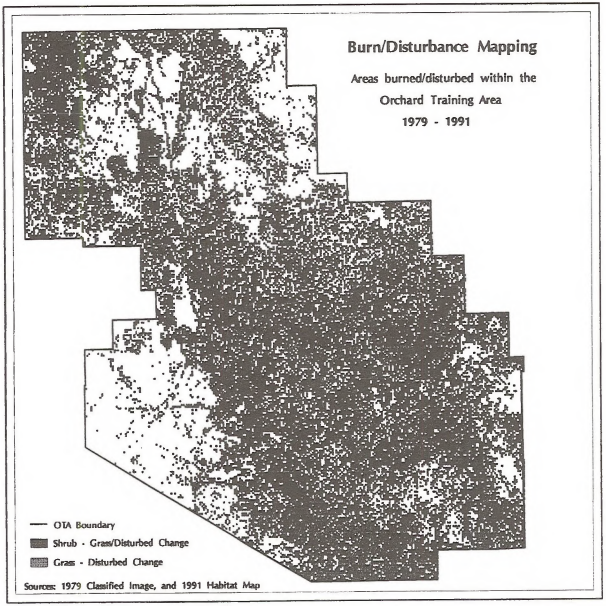

Fig. 5. Areas of burn/disturbance in the OTA using the 1979 classified image as base data.

same grass areas also showed very little disturbance on the current vegetation map; there was very little fire activity in many of these areas during 1979-1992, especially in the northern NCA.

Two situations have inflated the change figures between the 1979 MSS satellite classification and the current habitat map. One is that only actively growing agriculture is delineated in the imagery classifications vs. all agriculture (active and fallow) in the 1979 vegetation map. Because agriculture is not used in the change detection, more agriculture will eliminate area to be considered for change. Second, the 1979 vegetation classification has more shrub habitat than the 1979 vegetation map. This is partially explained by the classification of the MSS images; shrub was the dominant class - both in number of ground verified points used in the signature seed file for the classifier, hence more shrub classified (shrub n = 418, total n = 592), and the lack of mapping resolution in the 1979 vegetation map.

ACKNOWLEDGMENTS

We acknowledge the diligent efforts of the field crews for Study 5 of the Bureau of Land Management/Idaho Army National Guard Research Project for providing vegetation data for use in our efforts, and Dave Dyer for his work in converting the Global Positioning System data for the research efforts. This effort was funded by the Bureau of Land Management's Global Climate Change Program. This manuscript was reviewed by Deanna Dyer, Mike Kochert, and Karen Steenhof.

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1994 Monitoring Studies on Greenstrip Projects in the Snake River Birds of Prey National Conservation Area

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ANNUAL SUMMARY

Data collected in 1994 on the Disk Chain study site were highly variable and will not be presented at this time. A evaluation of monitoring procedures is planned for the 1995 field season to determine the cause of data variability.

OBJECTIVE

1. To monitor establishment and persistence of plants used to establish strips of fire resistant vegetation (i.e., greenstrips) in the Snake River Birds of Prey National Conservation Area (SRBOPNCA).

2. To document competitive interactions between an introduced and native shrubs.

METHODS

Most greenstrip projects are monitored with a procedure that combines cover, density, phenology and frequency data collection. This procedure, called "Freqdens", is described in a previously published report (Pellant 1989). Prior to 1989, a pace transect was used to monitor several greenstrip projects (Pellant 1992). All studies include photographs.

RESULTS AND DISCUSSION

During the 1994 field season, 20 study sites on 4 greenstrip projects in the SRBOPNCA were monitored. The data are being evaluated to assess the effects of an extended drought on greenstrip vegetation and adjacent plant communities. This information will assist managers in evaluating greenstrip project success over the last 8 years and plan future greenstrip projects.

Two study sites established in 1990 on an experimental greenstrip near Simco Road were re-sampled in 1994.

A site preparation and seeding machine (disk chain) was used to seed a crested wheatgrass (*Agropyron*

cristatum) and forage kochia (*Kochia prostrata*) mixture after a 1986 wildfire.

Forage kochia is an introduced half-shrub that is very competitive with cheatgrass (*Bromus tectorum*) and remains fire resistant throughout the summer. These studies document the competitive interactions between seeded and native species along 4 160-m transects. The transects originate at the greenstrip boundary and run into adjacent rangeland that was burned in the 1986 wildfire.

No data from these transects are presented in this report due to unexplained variability.

PLANS FOR NEXT YEAR

The study procedures and continuation of greenstrip project monitoring in the SRBOPNCA will be evaluated in 1995.

ACKNOWLEDGMENTS

L. Williams and S. Klug assisted in the collection of 1994 monitoring data.

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Seedling Ecology of Shrubs Associated with Snake River Plain Wyoming Sagebrush Vegetation

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ANNUAL SUMMARY

We documented natural regeneration of winterfat ***(Ceratoides lanata)*** *seedlings on 4 permanent sites that were established in 1994. All of the sites had seedling germination that occurred within the week of 5-12 March. After this period there was very little subsequent germination. We planted seeds (collected from each site in 1994) at the permanent sites during this week. Very few (<0.05%) of the seeds survived, and they appeared to have desiccated before cotyledon emergence. Individual naturally regenerated seedlings were documented with respect to density and microsite description. Average density ranged from 30 to 90 seedlings per m^2. We sampled the sites again in mid-March, May, June, and October. By October, the winterfat seedling survival ranged from 10 to 30% depending on the site. We analyzed the results of the successive samplings, and there appeared to be no correlation between seedling survival and microsite characteristics.*

We sampled the Wyoming big sage ***(Artemisia tridentata wyomingensis)*** *sites at the same time as the winterfat. At the time of the first sampling in March, seedlings had germinated and the density ranged from 250 to 790 seedlings per m^2 in 3 of the 4 permanent sites. One site (Poison Ck/Mud Flats) had 0 seedlings along the transect. Due to the large number of seedlings, individual seedlings were not documented. Seedling density was documented throughout the season, and 20 by 20-cm plots along a 50-m transect were described relative to microsite characteristics and the number of seedlings occurring within the plot. Seedling survival was very low in all sites (0.04% average), and there was no correlation between seedling survival and microsite characteristics.*

Winterfat and Wyoming big sage plants were sampled to establish possible correlation factors for a non-destructive age analysis. Stem diameter had the highest correlation, with the accuracy being best on plants 15 years of age and younger.

OBJECTIVES

1) Document survival of winterfat and Wyoming big sage seedlings with respect to their microsite environment.

2) Document the survival of winterfat seedlings planted in various microsite environments.

3) Determine shrub characteristics that correlate with plant age.

METHODS AND PLOT SAMPLING PROCEDURES

Winterfat

The 4 permanent winterfat sites were examined initially on 5 and 6 March. At this time naturally regenerated seedlings had sprouted, and all of the seedlings consisted of 2 cotyledons. We laid out 2 25-m permanent plots within the original winterfat sites to document seedling occurrence and survival during the 1994 season. Each seedling along the 25-m transect was mapped and its location was marked with a colored toothpick for later identification. Each seedling was described according to microsite characteristics. We also determined seedling density along the transect. There were abundant seedlings, and the average density within the plots ranged from 35 to 90 seedlings per square meter. All seedlings were at the same phenological stage.

At the same time that we mapped the germinated seedlings, we also planted seeds that had been collected during 1993. The seeds had been pretreated with 1 week of moist cold (0 - 4.4 C). Seeds were placed on the surface, in cracks, in clusters of litter, and in sites of disturbed soil. The seeds were placed and mapped along a transect, both randomly and on specific microsites and soil surfaces.

The sites were revisited the week of 14 March. Most of the naturally regenerated seedlings were still alive. Very few of the planted seeds had germinated , apparently dying due to desiccation. There was also no evidence that any naturally occurring seeds had germinated since the initial 'crop'. All existing seedlings were still in similar phenological stages - ranging from 6 to 8 leaves with a root depth of around 20 cm.

We revisited the sites during May and June and again in October. At least a third of the originally mapped seedlings had survived until October. During October, we also sampled several random winterfat sites in different areas. All seedlings in these sites were described relative to microsite characteristics. Preliminary analysis of the surviving seedlings indicated no significance relative to microsite differences. Although analysis is not complete, it seems that natural regeneration of winterfat may be more related to annual seed production than microsite characteristics. The summer of 1993 was relatively moist, and the seed crop was very large, as were the number of seedlings. There were very few seeds produced during 1994. Some sites had almost none, with only a few scattered plants producing any seeds at all.

Because winterfat regeneration may be more related to seasonal weather patterns than microsite differences, it would be of interest to do an age class analysis of winterfat stands to determine if some years had a higher rate of plant establishment than others. If so, this might relate to years of favorable growth for seed production, germination, or seedling survival. To estimate plant age without large scale destructive sampling, we sampled plants in several age groups to determine possible correlations between age and plant characteristics. Age was determined by growth ring counts. The characteristic most correlated with age was stem diameter. Correlation was very high on younger plants (< 15 years). Although age/stem diameter correlation was lower on older plants, it was still higher than any other trait. Hopefully an extensive age-class analysis can be performed during 1995 to

look for climatic patterns in winterfat natural regeneration.

Wyoming Big Sage

During the first week in March, we sampled the 4 permanent sagebrush sites. We determined seedling density for the sites and the density ranged from 250 to 790 seedlings per m^2 in 3 of the sites. One site (Poison Ck/Mud Flats) had 0 seedlings along the transect. There were too many seedlings to map individual survival, so we resampled the same sites for density during May and June. By June, only 1 site (Power Line) had many surviving seedlings, a reduction from 790/m^2 to 49/m^2. The other 2 sites were reduced to 8 and 1 seedling/m^2. We sampled the 4 permanent sites and several other random sites to locate and describe the microsites of any surviving seedlings. There were very few seedlings in any of the sites except the Power Line site. It appears that the Wyoming big sage seedlings were not able to survive the relatively dry summer in 1994 even though the initial germination was so abundant. The 1994 seed crop was much less than in 1993, with many plants producing no seeds at all. Those that did bear seeds, produced far fewer than in 1994.

PLANS FOR NEXT YEAR

Research during 1995 will consist of repeating the documentation of seedling survival relative to microsite differences with both the 1994 seedlings and any new (1995) seedlings. Because the seed crop in 1994 was extremely sparse, we do not anticipate many newly germinated seedlings, especially in the winterfat sites.

The Effects of Post-fire Rangeland Rehabilitation on the Recovery of Microbiotic Soil Crusts of the Western Snake River Plain

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ANNUAL SUMMARY

Fifty-four permanent transects were established to study the recovery of microbiotic soil crusts following fire and subsequent rehabilitation. Over a decade following treatment, microbiotic crusts in areas seeded with perennial grasses have reached early to mid-seral successional stages. Areas that were burned but not rehabilitated are dominated by annual grasses and forbs, and lack development of the climax microbiotic crust components found in the seeded and unburned sagebrush communities. Results of this study suggest that rehabilitation of the vascular vegetation and recovery of the microbiotic crust are closely tied.

OBJECTIVES

1. Assess the post-fire recovery of microbiotic soil crusts approximately 11 to 14 years following burning.

2. Determine if rehabilitation of the vascular vegetation of burned areas also enhances the recovery of microbiotic soil crusts.

3. Establish permanent transects for long-term monitoring of microbiotic crust recovery.

INTRODUCTION

Microbiotic soil crusts are components of shrubsteppe and desert shrub communities in arid and semi-arid ecosystems of the world. These crusts, composed of cyanobacteria, algae, microfungi, lichens, and bryophytes, occur primarily within the interspaces of the plant community. Research has demonstrated that intact soil crusts perform a number of vital functions in arid and semi-arid habitats, the most important being reduction of erosion by soil surface stabilization. Other roles played by microbiotic crusts include improvement of soil moisture status,

fixation of atmospheric nitrogen by cyanobacterial components, and primary production (St. Clair and Johansen 1993). Soil crusts in southwestern Idaho are often composed of 10 to 20 lichen species and up to 6 bryophytes, along with the less conspicuous algal and cyanobacterial component. In areas such as this where diversity of vascular plants is low, microbiotic crusts contribute to the biological and structural diversity of the plant community.

A number of factors have been documented that disrupt or destroy the structure and function of these crusts. These factors include trampling by humans and livestock, vehicular traffic, and fire (Eldridge and Greene 1994). Increased fire frequencies within the Snake River Plain have resulted in conversion of much of the area to annual grassland dominated by exotic species such as cheatgrass (*Bromus tectorum*) (Whisenant 1990). Extensive areas are seeded with perennial exotic and native grasses and native shrubs following fire.

METHODS

This study was designed to investigate the recovery of microbiotic soil crusts following fire and subsequent rehabilitation. Three sites were located on the western Snake River Plain within the Bruneau Resource Area, Boise District BLM: Kuna Butte East, Kuna Butte West, and Rattlesnake Creek, approximately 3 to 4 miles north of Mountain Home along U.S. Route 20. These sites support unburned Wyoming big sagebrush/ bluebunch wheatgrass (*Artemisia tridentata* ssp. *wyomingensis*/*Agropyron spicatum*) or Wyoming big sagebrush/Thurber's needlegrass (*A. t.* ssp. *wyomingensis*/*Stipa thurberiana*) communities; burned areas seeded with perennial grasses using a rangeland drill; and burned areas that were not seeded and are dominated by exotic annual grasses and forbs. Two of the sites (Kuna Butte East and Kuna Butte West) burned in 1983; the third site (Rattlesnake Creek) burned in 1980. Rehabilitation occurred during fall/winter following the fires.

During spring 1994, 6 permanent 20-m transects were established for each treatment within each site, for a total of 54 transects. Percent coverage of vascular and nonvascular vegetation, rock, bare ground, persistent and non-persistent litter along each transect was determined using the line intercept method (Canfield 1941). Samples of the top 5 cm of soil were collected adjacent to each transect and are currently being analyzed for soil texture, pH, electrical conductivity, presence of calcium carbonate, and color. These data will be used to characterize the surface soils for each site.

RESULTS AND DISCUSSION

Coverage of microbiotic soil crust components and cheatgrass are summarized in Table 1. Bryophytes were divided into 2 classes: tall moss (*Tortula ruralis*) and miscellaneous short mosses. *T. ruralis* is normally found beneath the canopies of shrubs and, to a lesser extent, bunchgrasses. Short mosses occur predominantly in interspace positions and beneath bunchgrass canopies. They are also found within annual grass communities where the litter layer has not accumulated to such a depth that it excludes light, approximately 1 cm. *T. ruralis* is abundant in the unburned sagebrush communities and is mostly absent from the burned/unseeded areas. *T. ruralis* was found in the burned/unseeded treatment at Rattlesnake Creek along a transect that ran adjacent to dead sagebrush, indicating that this area did not burn as intensely as the surrounding area. When recently burned sites were examined, *T. ruralis* was found surviving in similar, less intensely burned areas. In burned/seeded areas, this moss is found at the base of bunchgrasses, rarely extending into the interspaces.

In southern Utah, mosses have been reported as being part of the climax crust community and very slow to recover from disturbance (Belnap 1993). The results suggest that *T. ruralis* is just beginning to establish approximately 11-14 years following burning and rehabilitation, and that the moss needs shading and protection from bunchgrasses or shrubs in order to persist.

The short mosses were abundant in all treatments. Some of these mosses, such as *Ceratodon purpureus*, *Bryum argenteum*, and *Funaria hygrometrica*, are cosmopolitan in distribution and often found in disturbed sites. In disturbed sagebrush habitats in southwestern Idaho, they appear to be pioneer species and likely serve to

Table 1. Percent cover of microbiotic soil crust components and cheatgrass in burned/seeded, burned/unseeded and unburned sagebrush treatments.

Site Name	*Tortula ruralis*	Short mosses	Lichens	Total crust cover	*Bromus tectorum*
Burned/seeded					
Rattlesnake Creek	0.03	34.24	0.28	34.55	3.50
Kuna Butte East	2.96	39.41	0.40	42.77	0.33
Kuna Butte West	3.36	54.95	1.57	59.88	0.00
Burned/unseeded					
Rattlesnake Creek	2.28	4.53	0.03	6.84	49.99
Kuna Butte East	0.00	39.99	0.00	39.99	49.02
Kuna Butte West	0.00	57.44	0.01	57.45	60.55
Unburned sagebrush					
Rattlesnake Creek	38.78	17.69	10.44	66.91	0.00
Kuna Butte East	30.93	37.20	7.64	75.77	0.11
Kuna Butte West	34.63	14.39	6.39	55.41	0.30

stabilize the soil surface. Although they can be abundant in annual grass communities, these mosses are eventually excluded due to density of vegetation and persistent litter accumulation. Along some transects cheatgrass coverage exceeded 80%, at which point the mosses became absent.

In this study, lichens were also slow to recover from disturbance. Like *T. ruralis*, they were virtually absent from the burned/unseeded areas. The only lichen found here was *Caloplaca tominii*, a common species that disperses vegetatively. Coverage values were higher for the burned/seeded treatments, though not approaching the densities found in unburned sagebrush communities. At the Kuna Butte sites, diversity of species was similar to that of the unburned treatments.

Some lichen species are parasitic on mosses or grow on dead organic matter, such as *Poa secunda* mounds. Most lichens grow very slowly, at rates of approximately 1 mm annually. Thus, a well-developed lichen component is considered part of the climax stage for microbiotic soil crust communities and requires some development of vascular plants and bryophytes in order to establish and persist.

Cheatgrass coverage was minimal in the unburned sagebrush and burned/seeded treatments, but exceeded 90% for some transects in the burned/unseeded treatments. The results of this study suggest that the structure of the native plant community might be important for reestablishment of the crusts. Shrubs and bunchgrasses provide shading and moist microsites for propagation of those bryophytes that do not easily invade disturbed soil. This type of community structure does not produce a thick canopy or litter layer, like that of annual grasses, that eventually excludes the nonvascular species. Lichens eventually invade the area, with most species taking decades of freedom

from disturbance to persist and reach their former coverage levels. Early to mid-seral stages in microbiotic crust communities have been reached over a decade following disturbance for sites on the western Snake River Plain.

PLANS FOR NEXT YEAR

Extensive research has been done regarding the floristics and ecology of algal and cyanobacterial soil crusts in the southwestern United States. These components are much less obvious in the soil crusts in southwestern Idaho, and no studies have yet focused on them. During spring 1995, I will sample the study sites for soil algae and cyanobacteria. Species present and relative densities will be determined. This will provide some initial floristic data for these crust components on the western Snake River Plain.

During spring 1995, permanent monitoring transects will be placed in unburned, unseeded, and seeded areas of the 1994 Poen Fire. This cooperative study with the Boise District BLM will investigate the intial recovery of microbiotic soil crusts, including the algal/cyanobacterial element, during the first year following fire and subsequent rehabilitation.

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Environmental Monitoring in the Idaho Army National Guard Orchard Training Area

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ANNUAL SUMMARY

*We monitored 279 permanent land condition-trend vegetation/soil monitoring (LCTA) plots established in 1989-1991, and burrow counts of Townsend ground squirrels (**Spermophilus townsendii**, hereafter TGS) and badgers (**Taxidea taxus**) were monitored on the 60 traditional transects. We searched for and identified **Lepidium papilliferum** microsites north and east of Range Road/Orchard Road, and south of Orchard Road in the area between Range 6 and the northern boundary of the Orchard Training Area (hereafter OTA). This spring, **Texosporium sancti-jacobi,** a federal category 2 candidate lichen species, was found in the OTA. We monitored 60 photopoints in the north half of the impact area during the spring. Several previously unrecorded plant species were collected in the OTA and added to the herbarium.*

OBJECTIVES

To assess and monitor the land condition and vertebrate populations in the Orchard Training Area in order to minimize the impacts of National Guard training.

METHODS

Vegetation/Soils Monitoring

Individuals of *Lepidium papilliferum*, a federally listed category 2 candidate plant species (hereafter called LEPA) were counted on the 4 traditional 1.6-km walking transects, monitored in early June. Also in June, sagebrush communities in the OTA were searched, and a rough count of LEPA plants was made.

The demographic study of 12 *Lepidium papilliferum* microsites east of Range 6 continued. Once each month (except in snowy months), we monitored the microsites using the method described by Quinney (1993). The reproductive status of each tagged plant was recorded monthly. During the monthly counts of tagged plants, numbers of untagged, "new" LEPA plants were also recorded for each site. On 5 of the 12 sites, all untagged, "new" plants were tagged during each month's monitoring. Several of the microsites suffered from sheep damage in late April, and many of the tagged plants were killed.

All LCTA plots were monitored in 1994. On all LCTA plots with shrubs, belt transects were sampled in 1994. We monitored shrub belt transects using the methods outlined by Quinney (1990). All shrubs were counted on 1990 transplant special-use plots, using methods reported by Quinney (1990). A more detailed explanation of the LCTA methods used in the Orchard Training Area can be found in the U.S. Army Land Condition Trend Analysis (LCTA) Field Methods manual (U.S. Army Corps of Engineers 1987).

In April and May, the 50 photopoint locations in the north polygon formed by Range Road and the livestock drift fence were monitored, using the procedure outlined in the 1991 annual report (Quinney et al. 1991).

Vertebrate Monitoring

In June and July, the 60 LCTA plots sampled in previous years were censused for Townsend's ground squirrel and badger holes, using the method described by Quinney (1990).

In 1994, we did not monitor OTA reptiles. LCTA crews recorded in their field notes those encountered during vegetation monitoring activities. No previously unrecorded reptile species were noted for the OTA in 1994.

RESULTS

Vegetation monitoring

In 1994, the 281 LCTA plots were inventoried. We counted all shrub seedlings on the 8 native shrub transplant plots established in 1990.

LCTA data collected are on file in the office of the U.S. Army Corps of Engineers Research Laboratory, Champaign, Illinois, the Boise District Bureau of Land Management, the Center for the Management of Military Lands at Colorado State University, Fort Collins, Colorado, and at the Idaho Army National Guard Environmental Management Office, Gowen Field, Boise, Idaho.

Walking surveys were done in June to provide a rough estimate of 1994 LEPA numbers in the OTA. We counted approximately 53,240 living individuals.

Information collected on LEPA in 1994 is on file in Boise, Idaho, at the Army National Guard Environmental Management Office. LEPA demographic data have been sent to Dr. Susan Meyer of the U.S.D.A. Forest Service Intermountain Research Station Shrub Sciences Laboratory in Provo, Utah, where they are being compiled and analyzed. In 1994, "Off Limits to Military Personnel" signs were erected around the major LEPA populations in the OTA.

Several vascular plant species not previously recorded from the OTA were collected and identified (see Appendix A). Specimens collected were sent to Colorado State University for confirmation of species identifications and for herbarium mounting. Herbarium voucher specimens of the new plant species collected in 1994 will be archived in the herbarium of Colorado State University, Fort Collins, Colorado; duplicate specimens will be added to the Idaho Army National Guard herbarium.

In 1994, the federal category 2 candidate lichen species, *Texosporium sancti-jacobi*, was found in the OTA. *T. sancti-jacobi* was found in the area already protected from military training because of the presence of LEPA, north and east of Range Road/Orchard Road, and south of Orchard Road in the area between Range 6 and the northern boundary of the Orchard Training Area.

In 1993, a concern was the first-time appearance of the perennial composite rush skeletonweed, *Chondrilla juncea* L., in the OTA (Quinney 1993). Approximately 1 ha of OTA *Chondrilla* infestation was found in 1993; these plants were uprooted. In July 1994, the area of 1993 OTA infestation was revisited, and no *Chondrilla* plants were found. However, we did note a large infestation of this species (approximately 4 km^2) outside the OTA on both sides of Simco Road, with the apparent center of the infestation near the Simco Road railroad crossing.

Vertebrate Monitoring

The 60 traditional TGS and badger hole-count transects were sampled during June and July 1994. TGS and badger hole-count data are on file in the office of the U.S. Army Corps of Engineers Research Laboratory, Champaign, Illinois, the Center for the Management of Military Lands at Colorado State University, Fort Collins, Colorado, and at the Idaho Army National Guard Environmental Management Office, Gowen Field, Boise, Idaho.

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Appendix A. Plant taxa not previously recorded from Orchard Training Area. These species were collected in 1993 and identified in 1994, with the exception of *Texosporium sancti-jacobi*, which was collected and identified in 1994.

Antennaria dimorpha (Nutt.) Torr. & Gray
Sariocarpus kingii (S. Wats.) (N.) D. A. Sutton
Astragalus beckwithii Torr. & Gray
Chaenactis stevioides Hook. & Arn.
Cryptantha circumscissa (Hook. & Arn.) I.M. Johnston
Cryptantha gracilis Osterhout
Cuscuta pentagona Engelm.
Gayophytum ramosissimum Torr. & Gray
Gnaphalium palustre Nutt.
Ipomopsis minutiflora (Benth.) V. Grant
Lappula occidentalis (S. Wats.) Greene
Malacothrix glabrata (D.C. Eat. ex Gray) Gray
Matricaria perforata Merat
Mimulus sucksdorfii Gray
Monolepis nuttalliana (J.A. Schultes) Greene
Texosportum sancti-jacobi (Tuck.) Nadv.
Tragopogon dubius Scop.

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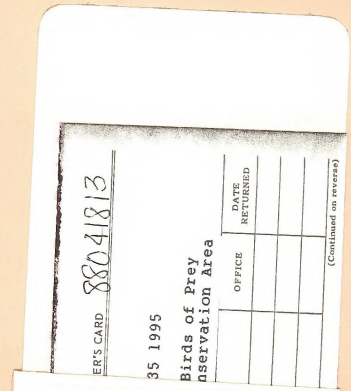

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